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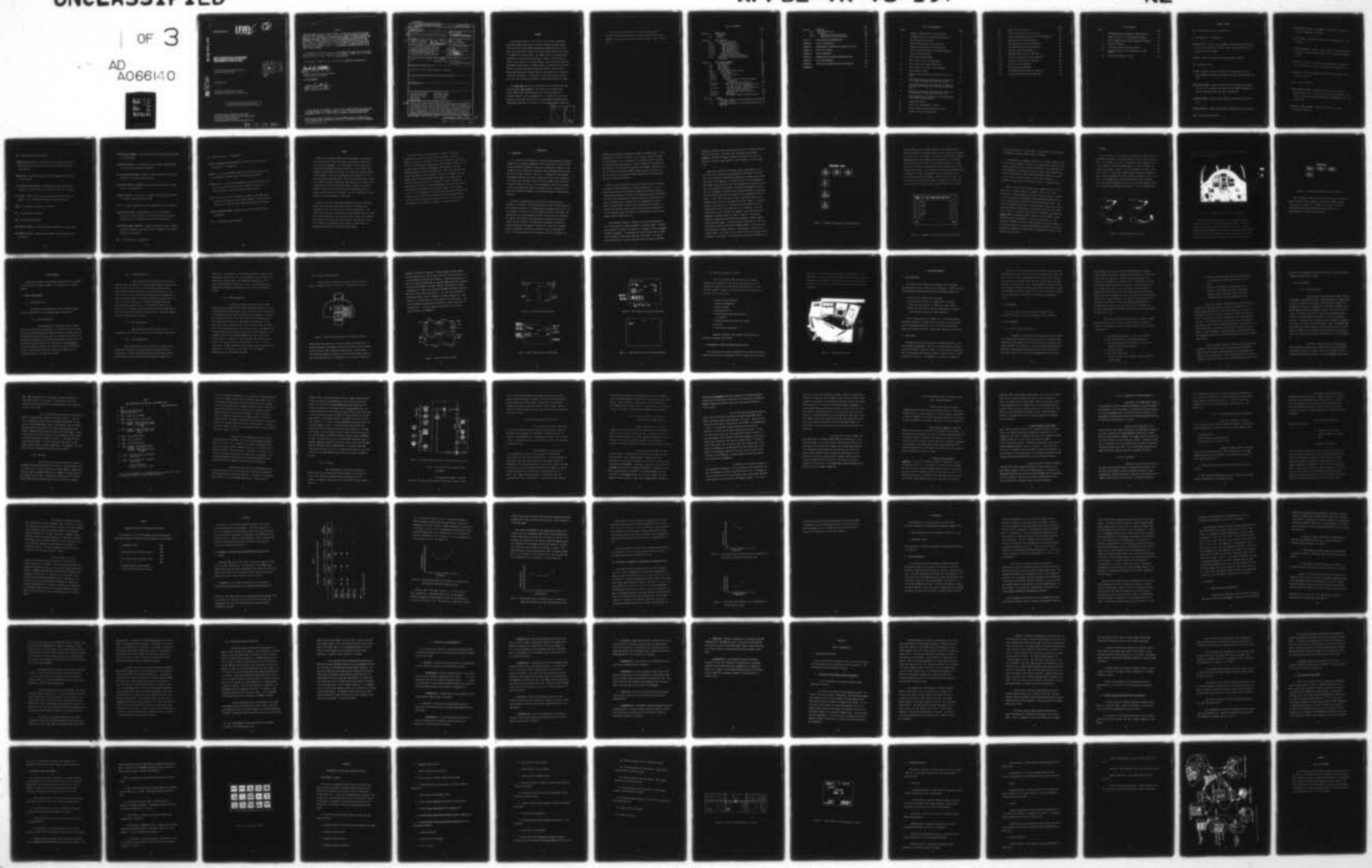

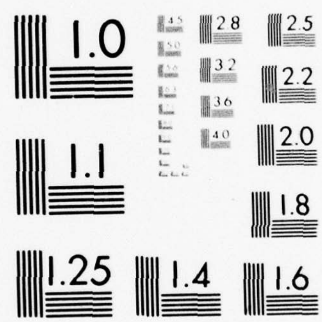
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AFFDL-TR-78-197

MULTIFUNCTION KEYBOARD IMPLEMENTATION STUDY

CREW SYSTEMS DEVELOPMENT BRANCH
FLIGHT CONTROL DIVISION

DECEMBER 1978

TECHNICAL REPORT AFFDL-TR-78-197
Final Report for 1 April 1976 – 11 February 1977

Approved for public release; distribution unlimited.

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Control Logic	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

AN Aircraft which utilize digital computers will require the use of multifunction controls and displays. Four different multifunction keyboard configurations were examined by pilots flying a simulated mission. Two of the configurations were located on the left side of the front instrument panel, while the remaining two were located on the right side console and/or the right side of the front instrument panel. The pilots performed communications, navigation and stores tasks using each configuration. The configurations also utilized two different types of hardware: projection switches and cathode ray tubes.

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FOREWORD

This Technical Report is the result of a work effort performed by the Digital Applications Group of the Crew Systems Development Branch (FGR), Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. Major Robert Bateman is the group leader and Dr. John Reising is responsible for human factors. Mr. Emmett Herron of the Bunker Ramo Corporation is tasked with providing pilot inputs to the work efforts, and Ms. Gloria Calhoun of the same company is tasked with statistical and experimental design inputs. Software support was provided by Mr. William Wessale of Systems Consultants Incorporated and Mr. Larry Evilsizor of Bunker Ramo Corporation; hardware support was provided by Mr. Al Meyer of Technology Incorporated. The objective of this effort was to evaluate the use of four multifunction keyboard configurations within the cockpit.

The Bunker Ramo portion of the work effort was performed under USAF Contract Number F33615-76C-0013. The contract was initiated under Project Number 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles" which is managed by Mr. J.H. Kearns, III, as Project Engineer and Principal Scientist for the Crew Systems Development Branch (AFFDL/FGR) Flight Control Division, Air Force Flight Dynamics Laboratory.

This effort was performed as part of the Digital Avionics Information System (DAIS) Advanced Development Program under Work Unit 20490202. This report includes work performed between 1 April 76 and 11 Feb 77.

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GLOSSARY OF TERMS

AAE - average absolute error - See Appendix G.

AE - average error - see Appendix G.

BRANCHING LOGIC - control logic programmed in parallel with system operation so that each switch activation causes various sublevels for the applicable system to appear.

CDC 6600 - Control Data Corporation general purpose computer.

CRT - Cathode Ray Tube.

CRT MFK - hardware in which the legends on a display adjacent to the switch changed according to the function the switch was serving at the time.

DATA ENTRY KEYBOARD - panel with twelve dedicated switches; the switches were in a 4 X 3 telephone type layout with the CLEAR and ENTER keys on the left and right sides of the zero, respectively.

DEDICATED DISPLAY - single display capable of performing only one function.

DEDICATED SWITCH - single switch capable of performing only one function.

DEK - see data entry keyboard.

ELECTRO-OPTICAL DISPLAY - programmable electronic display on which a variety of symbology can be shown.

FIGURE OF MERIT - statistical procedure used in data analysis - see Appendix G.

FLIGHT MODE SWITCHES - dedicated switches, which in the present study, determined the status display format and the logic page displayed on the MFK.

FLIGHT PLAN - AF Form 70 specifying radio frequencies, IFF modes, and codes, TACAN channels, waypoint coordinates, and weapon options.

FLYING TASK - maintaining groundspeed and keeping the flight director centered on the VSD.

FOM - see Figure of Merit.

FUNCTION SELECT SWITCHES - dedicated switches that when activated, determined which set of logical functions were to be addressed. The function select switches labeled COMM, NAV and STORES were used in the present study.

HORIZONTAL SITUATION FORMAT - cathode ray tube used to present navigation information.

HSF - see Horizontal Situation Format.

INFORMATION LOGIC DESIGN - determination of the meaning or function of each switch and the sequence of actions the pilot used to perform required tasks.

KEYBOARD TASK - operating the MFK to complete communication, navigation and stores tasks.

LATIN SQUARE DESIGN (BALANCED) - experimental design in which any one treatment is preceded equally often by each of the other treatments.

LOGIC LEVELS - means by which pilots selected and executed tasks; each change of a set of legends constituted a single logic level.

MANOVA - see Multivariate Analysis of Variance.

MFK - see Multifunction Keyboard.

MPD - see Multipurpose Display.

MULTIFUNCTION CONTROLS - several multifunction switches on a single panel.

MULTIFUNCTION DISPLAYS - single display capable of performing more than one function.

MULTIFUNCTION KEYBOARDS - several multifunction push button type switches on a single panel.

MULTIFUNCTION SWITCH - a switch whose function changes, depending upon the task being performed by the operator.

MULTIFUNCTION SWITCH LEGEND - name on or associated with a switch which identifies the switch's current function.

MULTIVARIATE ANALYSIS OF VARIANCE - statistical procedure used in data analysis - see Appendix G.

OPERATING SEQUENCE - logic levels or sequence of actions the pilot used to complete required tasks on the MFK.

PDP 11/45 - Digital Equipment Corporation general purpose mini-computer.

PROJECTION SWITCH MFK - hardware made up of switches having the capability to display different legends by selectively projecting different parts of a filmstrip onto the switch front surface.

RAMTEK RASTER SYMBOL GENERATOR - a display system which converts computer generated alphanumeric and graphic display information into industry compatible video signals.

RMS - root mean square - see Appendix G.

SD - standard deviation - see Appendix G.

STEPWISE DISCRIMINANT FUNCTION ANALYSIS - statistical procedure used in data analysis - see Appendix G.

SUBTASK - set of specified MFK and DEK selections which logically could be considered a complete task if accomplished independently.

TAILORED LOGIC - control logic programmed according to what functions are most likely to be used in the current flight mode-sublevels for several systems are available without switch activation.

TASK - operation the pilot was required to complete on the MFK. Each task involved either one task or several subtasks. No more than one activation of a function select switch was required for each task.

VERTICAL SITUATION FORMAT - cathode ray tube used to present flight information.

VSF - see Vertical Situation Format.

SUMMARY

Multifunction keyboards (MFKs) have been designed to integrate the many dedicated control functions found in present day cockpits into a more efficient arrangement. The primary purpose of this study was to examine pilot performance during the operation of four different MFK hardware configurations during flight in a single-seat cockpit simulator of A-7D geometry. Two of the configurations were located on the left side of the front instrument panel, while the remaining two were located on the right side console and/or the right side of the front panel. The configurations utilized two different types of hardware: projection switches (legend on the switch face) and CRT (legend presented on a display surface adjacent to the switch). All four configurations used a telephone type digit keyboard for data input.

Analysis of data recorded during communication changes, navigation updates, and weapon selections showed that pilot performance was consistently better with the projection switch configurations. The pilots stated that they preferred these configurations because the legend was located on the switch, and they did not have to make the association of the switch with the display surface legend. The additional search time involved in associating the switch with the proper legend in configurations utilizing a CRT penalized performance.

A secondary purpose of the study was to conduct a preliminary evaluation of the ease of calling up data on the MFK. In order to examine this question, two types of logic trees (branching - four steps, tailored - two steps) were implemented for UHF frequency changes. It was concluded that the design and implementation of MFK logic can have significant effects on pilot performance, and that logic tailored to the flight mode produces faster operation. The fact that significant time savings can be realized on the UHF task implies that savings on more difficult tasks may result in a considerable reduction in workload. Additionally, the pilots were quite enthusiastic about the MFK concept and indicated a preference for the Tailored Logic in their informal reactions. It is suggested that the Tailored Logic should be used as the primary logic in actual aircraft applications. The Branching Logic should also be implemented concurrently so that the pilot can access infrequently used functions not available in the Tailored Logic.

1. INTRODUCTION

1.1 BACKGROUND

As a result of the significant increase in the application of digital computers to the avionics subsystem of both military and civilian aircraft and the flexibility afforded by the ability to minaturize digital circuits through the use of large scale integration, more subsystems and more information can be made available to the pilot. If dedicated, single purpose instruments and switches are used to display and control this information, it is likely that locations outside the pilot's primary reach and vision envelope will have to be used. As the information continues to increase, it will not be physically possible to provide room in a cockpit for the multitude of dedicated displays or the increased number of single-purpose controls.

One means of optimizing location in terms of reach and vision envelopes is to provide a single, multifunction control from which many of the aircraft's functions, e.g. communications, navigation, and stores, can be controlled. In addition, such multifunction controls and displays also prevent the pilot from becoming overloaded by restricting the information on controls and displays so only that which is relevant to the pilot's current task is available. By changing the information contained on cockpit displays and the purpose of switches as a function of changing mission requirements, the digital computer not only can simplify the pilot's task of performing routine functions, but also can optimize the

information presentation and reduce the number of switches needed. Pilot workload may be reduced in two ways. First, several functions relevant to a mission phase can be consolidated in an optimal location, reducing the search task and reach envelope. Second, unnecessary information may be eliminated, reducing clutter and cross check problems. Realization of the full power of the digital computer depends upon the ability of the pilot to interpret the different display formats and to properly select the correct multifunction switch.

The Air Force has conducted a series of research efforts to examine the impact of digital computers on cockpits (References 1, 2, 3, 4). These efforts have centered around the engineering problems involved in integrating the sensors, processors, and displays/controls in the digital aircraft, and the human factors problems involved in piloting this aircraft. The human factors research initially emphasized the electro-optical display formats. However, early in these research efforts it became clear that multifunction controls were equally as important, if not more important, than the displays in determining the success of the digital aircraft cockpit (Ref. 5).

A multifunction control is composed of several switching devices, each of which may have different purposes at different times. Obviously if the purpose of a switch is changing, it is important that its <u>current</u> purpose be displayed. To accomplish this, multifunction switch legends must be changed to reflect what operation they control. One type of multifunction switch, called a projection switch, displays a different

legend by selectively projecting different parts of a film strip onto the switch front surface. In another type, the legend on the display adjacent to the switch changes according to the purpose the switch is serving at the time. Each change of a set of legends is called a logic level.

Since only a portion of the control options are available at each logic level (each switch has only one purpose at one time), one of the most critical aspects of multifunction switching is determining the steps required for task completion. The design process involves determining what purpose each switch will serve and the sequence of actions the pilot must use to perform required tasks. One means of designing the control logic is to program it in parallel with subsystem operation so that each switch activation causes various sublevels for the applicable system to appear. In the study, this type of control logic was referred to as Branching Logic and can be illustrated as shown in Figure 1. Typically, tasks are initiated by a set of dedicated switches which are used to determine which set of logic functions will be addressed. These are called function select switches. For example, a multifunction control designed for aircraft cockpits is shown in Figure 2. The drawing represents a Cathode Ray Tube (CRT) with push button switches mounted along the outside edges. If the switches are push buttons or keys, the device may be called a multifunction keyboard (MFK). Across the top of the CRT display are nine, dedicated, single-purpose, function select switches which, if activated, call up a particular set of options, which constitute a logic level. The multifunction switches are mounted on the

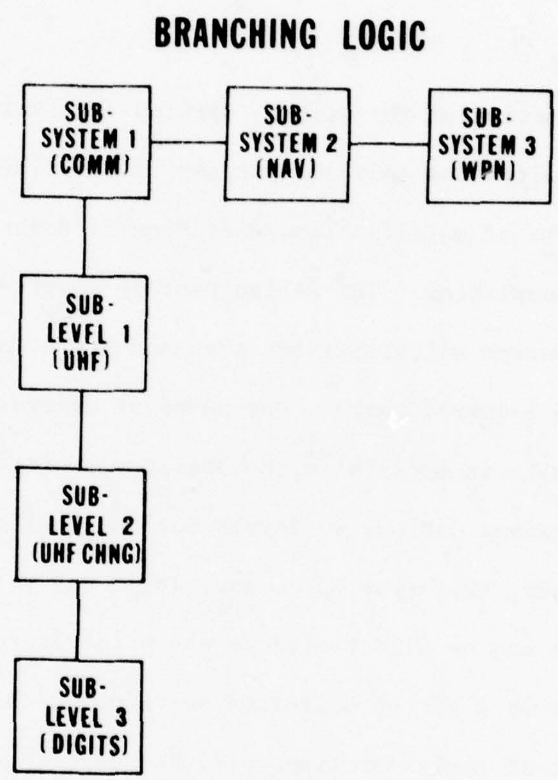


Figure 1. Schematic Representation of Branching Logic

left and right sides of the CRT. When one of the function select switches is pushed, the legends relative to that function are displayed on the CRT next to the switches. For example, when the switch labeled COMM (abbreviation for communication) is selected, a set of radios assigned to that function will be displayed (see Figure 1). At this logic level, each of the radio options is associated with one of the multifunction switches. The next step in the control sequence would be for the pilot to select the specific radio to be operated. This selection would change the legends so that, at this logic level, the pilot could turn on the radio, change a frequency, etc. Thus, each switch activation sets up new switch legends which identify new pur-

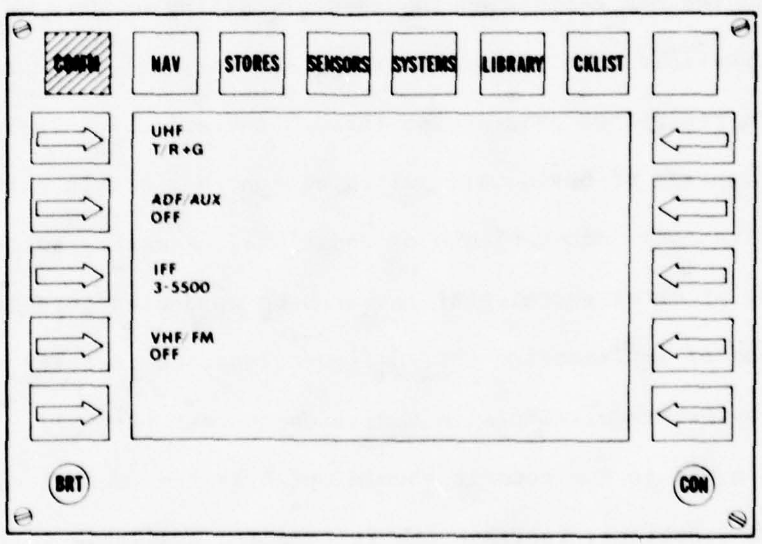


Figure 2. An Example of One Type of Multifunction Control

poses for each switch. In this manner, a great number of operations may be completed using only a small number of switches.

The MFK provides tremendous freedom for the cockpit designer in that he can allocate a number of functions to a single control panel and, thus, reduce the number of control heads and switches in the cockpit (Ref. 6). This design helps the pilot by providing a single, easily reachable keyboard with which he may control several different systems. As a result, cockpit clutter is reduced, panels in hard-to-reach places are eliminated, and switch actions become the same, i.e., pushes buttons.

However, there are some important issues regarding the use of the MFK that the cockpit designer must consider. First of all, pilot acceptance of the MFK depends on the ease of calling-up data on the MFK. It is quite possible that operation of the conventional dedicated controls is more rapid than progression through the switching logic. However, the advantage of having all switching controls within easy view and reach may offset the inconvenience of additional necessary switch operations. Thus, it is essential that research be conducted to determine the optimal method of implementing MFK configurations and identify the data display and switch requirements in a mission context (Ref. 7). The inclusion of a MFK in the cockpit should optimize the control capability of the switch functions, increase the information available to the pilot, and make the completion of required tasks, including all the controls and displays, more efficient.

1.2 PURPOSE

The main purpose of the study was to determine the optimal method of implementing a multifunction keyboard (MFK) for fighter cockpit applications. To accomplish this, pilot performance on tasks completed on four different MFK configurations during flight in a cockpit simulator was examined (see Figures 3 and 4). Two of the configurations were located on the left side of the front instrument panel, while the remaining two were located on the right side console and/or the right side of the front panel. The configurations utilized two different types of hardware: projection switches (legend on the switch face) and CRT (legend presented on a display surface adjacent to the switch). All four configurations

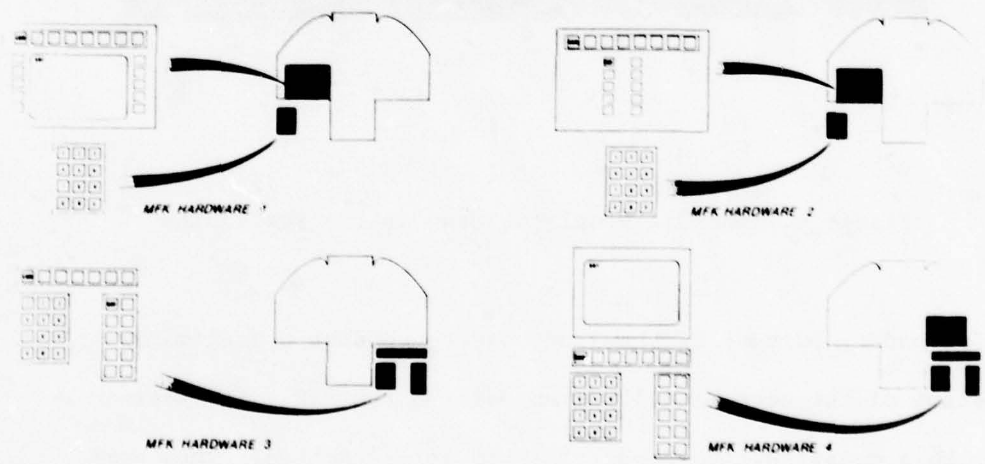


Figure 3. MFK Configurations Evaluated

used a separate, dedicated telephone type digit keyboard, with the addition of CLEAR and ENTER keys.

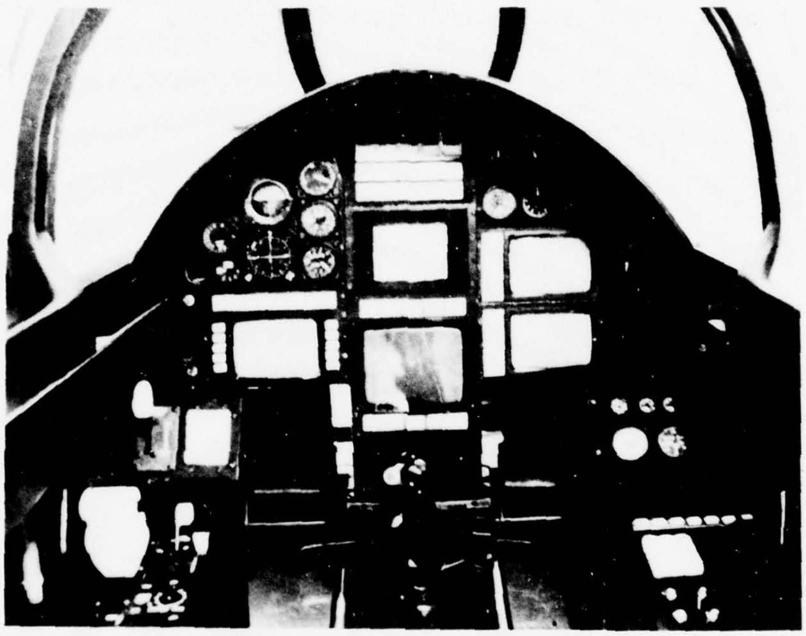


Figure 4. Cockpit Simulator Used in the Evaluation

A secondary purpose of the study was to conduct a preliminary examination of the ease of calling up data on the MFK. In order to examine this question, two types of logic were examined. They were Branching Logic (programmed in parallel with subsystem operation; Figure 2) and Tailored Logic (programmed according to what functions are most likely to be used in the current phase of system operation; Figure 5).

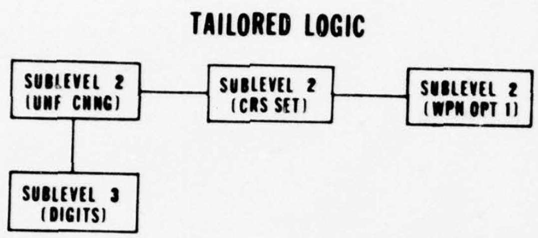


Figure 5. Schematic Representation of Tailored Logic

The test design provided for the analysis of the pilot's ability to maintain specific flight parameters and operate the MFK to complete various mission related tasks. Subjective evaluations of the MFK configurations and display formats were also obtained by the administration of a debriefing questionnaire.

2. TEST APPARATUS

A single-place cockpit of A-7D geometry was fabricated to accomodate the electro-optical displays and MFKs. The cockpit layout is shown in Figure 4.

2.1 COCKPIT CONFIGURATION

2.1.1 MFK Configurations

The hardware and implementation of the four MFK configurations are described in the following paragraphs (see Figure 3).

2.1.1.1 MFK Configuration 1

MFK configuration 1 consisted of eight dedicated push button function select switches in a row across the top of the CRT and ten push button multifunction switches mounted in columns on the left and right sides of the CRT. Only seven of the dedicated function select switches were operable and had legends displayed on the switch face. For the ten multifunction switches, the legend on the display adjacent to each switch changed according to the function the switch was serving at the time. These switches were only operable when information was displayed adjacent to the switches on the CRT.

2.1.1.2 MFK Configuration 2

MFK configuration 2 was mounted on the left front instrument panel and consisted of 18 push button switches. Seven of the eight switches across the top served as dedicated function select switches and had legends displayed on the switch front surface. The other ten switches were multifunction switches having the capability to display different legends by selectively projecting different parts of a film strip onto the switch face. No switch/legend association was required with this hardware type -- the legends were located on the switch face. The legends on these projection switches were appropriate to the function each switch was serving at the time. Only those switches displaying information were operable.

2.1.1.3 MFK Configuration 3

MFK configuration 3 used the same hardware as configuration 2, but located it on the right side console of the cockpit.

2.1.1.4 MFK Configuration 4

MFK configuration 4 was also located on the right console. The keyboard consisted of the same 18 push button switches used in configuration 3. Seven of the eight switches across the top served as dedicated function select switches and had legends displayed on the

switch face. The legends for the multifunction switches, however, were not located on the switches, but rather appeared on a CRT located on the right front instrument panel. The legends were appropriate to the function each switch was serving at the time. The switches were only operable when information corresponding to the switch was displayed on the CRT.

2.1.1.5 MFK Implementation

Although the hardware for three of the four MFK configurations was mounted in the cockpit during the simulation, only one of the four MFK configurations was active during a test run. The switches on the MFK being tested became operable when the experimenter initiated a task and remained operable until task completion. The data entry keyboard (DEK) being tested (left console DEK in Configurations 1 and 2, right console DEK in Configurations 3 and 4) became operable and lighted when the pilot was required to select and enter digits. The DEK consisted of twelve dedicated push-button keys; the switches were arranged in 4 X 3 telephone layout with the CLEAR and ENTER keys on the left and right sides of the zero, respectively. For some tasks, the letter N, S, E, W, X, and Y could be selected on the keys labeled 2, 8, 4, 6, 7, and 9, respectively. The MFK and DEK not being examined remained inoperable and unlighted for the duration of the flight. All four hardware configurations were functionally redundant.

2.1.2 Electro-optical Displays

Electro-optical displays were used in the present study to provide information to the pilot (Figure 6). The Vertical Situation

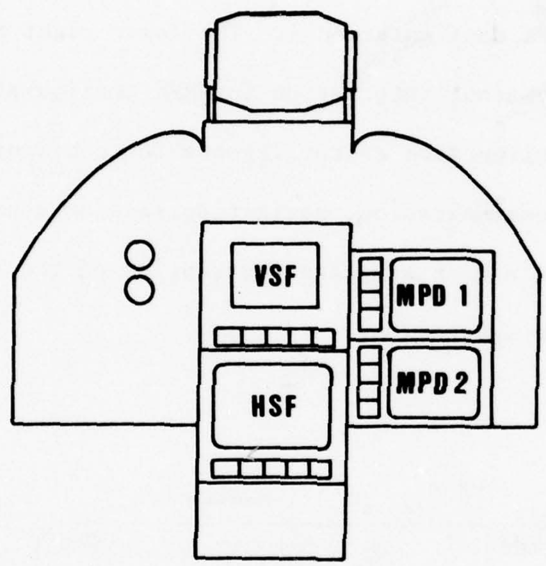


Figure 6. Electro-optical Displays in the Cockpit Simulator

Format (VSF) was presented on a six-inch diagonal color CRT (Figure 7). The VSF presented the information available on the conventional Attitude Director Indicator (ADI) along with additional data. The Horizontal Situation Format (HSF) was presented on an seven-inch diagonal black and white CRT and consisted of a representation of the route of flight and

navigation information (Figure 8). The Multipurpose Displays (MPDs) which displayed mission related data to the pilot were presented on two six-inch diagonal black and white monitors. In MFK configurations 2, 3, and 4, the upper right MPD (MPD 1) displayed communication and navigation data during the CRUISE flight mode (Figure 9) and displayed the same information plus stores data during the NAV BOMB flight mode (Figure 10). MPD 1 was blank in MFK configuration 1. The lower right MPD (MPD 2) presented pre-entry readout information for MFK configurations 2 and 3 (Figure 11), the multifunction switch legends for configuration 4, and status information (communication, navigation, and/or stores data) for configuration 1. For a more complete description of the electro-optical displays, see Appendix A.

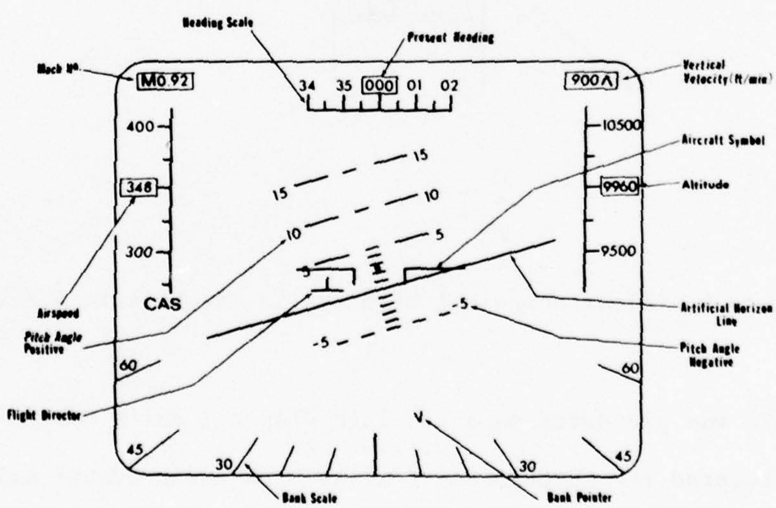


Figure 7. Vertical Situation Format

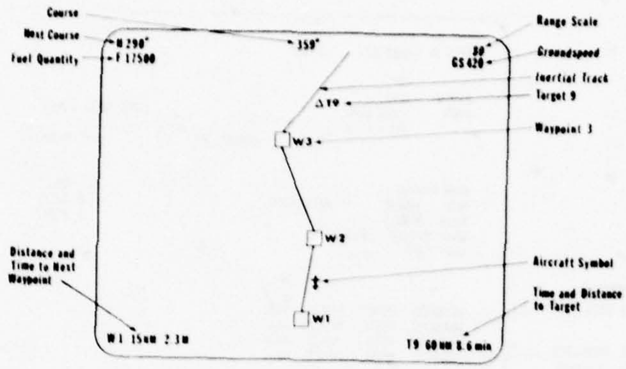


Figure 8. Horizontal Situation Format

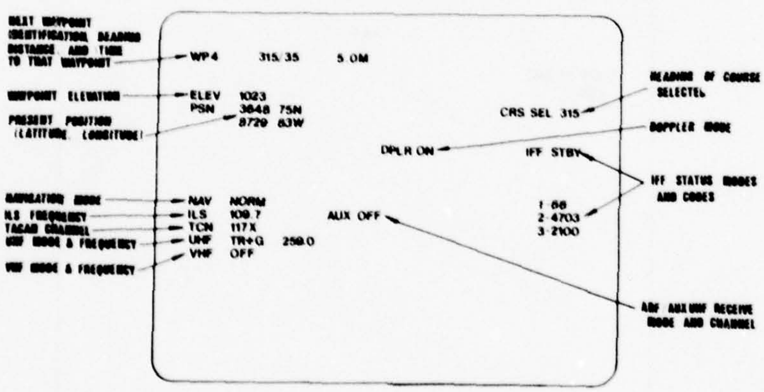


Figure 9. MPD 1 Format for Cruise Flight Mode

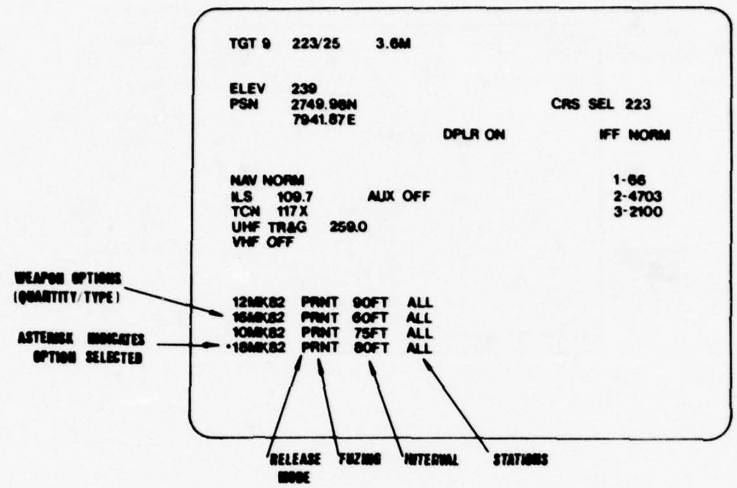


Figure 10. MPD 1 Format for Nav Bomb Flight Mode

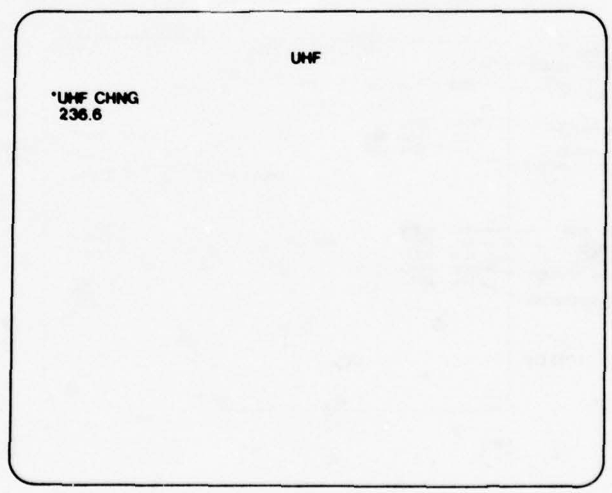


Figure 11. MPD 2 Format for Pre-entry Task Information

2.1.3 Dedicated Displays and Controls

Most of the backup flight instruments in the cockpit simulator were inoperable so that the pilot was forced to use the information displayed on the VSF and HSF to maintain control of the aircraft simulator. However, the following devices were operable and available for use by the pilot:

a) Angle of Attack Indicator
b) Engine Instrumentation
c) Pitch Trim Knob
d) Master Arm Switch
e) Trim Button and Bomb Release Button on the Stick
f) Cruise and Nav Bomb Flight Mode Switches
g) Throttle
h) Control Stick and Rudders

Appendix A provides a more complete description of the dedicated instruments and switches.

2.2 EXPERIMENTER'S CONSOLE AND SIMULATION FACILITIES

The experimenter's console was equipped with CRT displays and status lights which provided the experimenter with the capability of monitoring

the displays in the simulator and the switch actions (Figure 12). The experimenter could also control the initiation of keyboard tasks and the termination of test flights. A layout and description of each piece of equipment on the console that was used in the present study is provided in Appendix B.

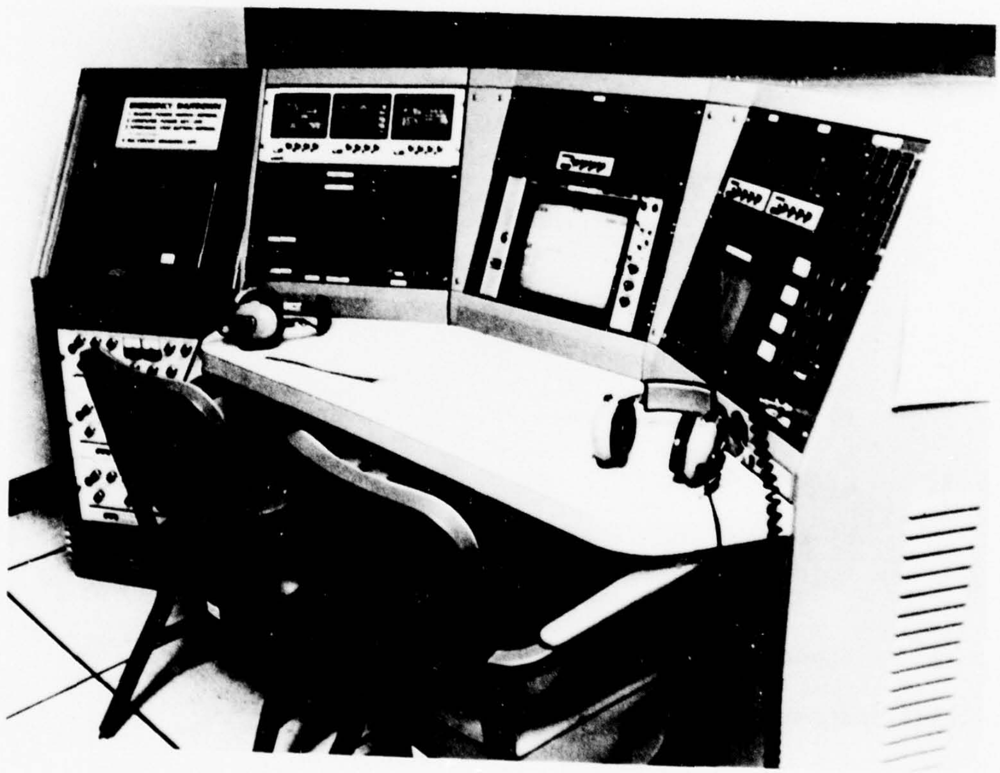


Figure 12. Experimenter's Console

3. TEST METHOD/APPROACH

3.1 TEST OBJECTIVES

The purpose of this study was to determine which of the MFK configurations is best in terms of pilot performance. Briefly, the four different MFK configurations examined during simulated flight were:

1) CRT version of a MFK on the front panel,
2) Projection switch version of a MFK on the front panel,
3) Projection switch version of a MFK on the right console,
4) MFK on the right console with the corresponding multifunction switch legends displayed on a right panel CRT.

The test design provided for analyses of: (1) several objective performance measures for flight director deviations in pitch and bank axes and groundspeed deviations; and (2) two objective performance measures for keyboard operation. Questionnaire data was also obtained.

3.2 TEST DESIGN

Performance for each pilot subject was observed under each of the four keyboard configurations. Only one of the four keyboard configurations was evaluated in each test flight. The pilots flew one flight with each of the keyboard configurations, making a total of four test flights scheduled for each pilot. (See Appendix C for daily test schedule).

The order in which the pilots flew each keyboard configuration was determined by the restrictions required for a balanced Latin square such that a flight with any one configuration was preceded equally often by each of the other configurations. Four missions having the same number and type of task events were used. The missions were randomly assigned to the flights such that each mission was flown the same number of times with each MFK configuration. Specific task order and data entry information was independently randomized for each mission (see paragraph 3.4.2.1).

3.3 TEST SUBJECTS

A total of sixteen A-7D pilots served as subjects in this experiment. The subject pilots had an average of 2564 flying hours.

3.4 TEST PROCEDURE

3.4.1 Pilot Briefing and Training

Throughout the briefing and training phases of the experiment the procedures were standardized such that each pilot received the same information and opportunity for familiarization with the keyboard logic, cockpit simulator, and procedures. Initial briefings and training were conducted for small groups at the subject pilots' home base prior to their participation in the testing at Wright-Patterson Air Force Base.

After familiarizing the pilots with the advanced "digital" airplane cockpit concept, the controls, displays, and procedures to be used in the current study were explained. Training related specifically to the operation of the MFKs was then given in order to familiarize the pilots with the logic trees for each type of task to be completed during the test flights. Each subject pilot participated in a briefing where a random access slide projector and control panel made up of push button switches was used to simulate some of the available functions on the MFKs mounted in the cockpit simulator. The purpose of this training was to familiarize the pilots with multifunction switches and progression through task logic levels. Also, the subjects heard a detailed logic briefing involving MFK logic packages which showed the operating sequence for each type of task.

After the home base training, each pilot traveled to Wright-Patterson Air Force Base for on-site cockpit simulator briefing and testing. The information explained or demonstrated during the briefing is noted below.

1) The symbology and dynamics of the display formats
2) The type and location of each MFK configuration
3) The operating sequence for each type of task to be completed during the test flights
4) The pilot's tasks
5) Procedural instruction
6) Pre-entry readout, error messages, status information, and MPD formats

7) Correction procedures after entering the wrong digits or incorrectly progressing through the logic level steps

8) The use of the throttle, pitch trim knob, stick switches, backup flight instruments, flight mode switches, engine instruments, master arm switch, intercomm system, and switch brightness controls

During the briefing, a demonstration was given in which the displays were illuminated and the keyboards were operable, but the scoring program was inactive. The airplane model was also placed in a "hold mode" so that the pilot was not required to "fly" the simulator while he practiced the selection of appropriate logic level options for each task. The keyboard practice was such that each pilot completed operations on three of the four MFK configurations. The operation of the fourth configuration, although not actually experienced by the pilot because of time constraints in changing hardware, was explained to him. The configuration that was not activated during the briefing was balanced across pilots.

After the cockpit briefing, a simulation training flight was conducted in order to give the pilot experience with the handling qualities of the simulator, keyboard operation, and operational procedures of the test conditions. During the training flight, the pilot completed at least five tasks on the three MFK configurations used in the

briefing. The configuration that was not activated during the training flights was balanced across pilots.

3.4.2 Test Flights

3.4.2.1 Mission and Tasks

Four missions involving simulated flight in CRUISE and NAV BOMB flight modes were used. (Additional mission information and the initial conditions for each mission are provided in Appendix D.) Throughout each flight, the symbology and information displayed on the VSF and HSF were dynamic in response to thrust, bank, yaw, and pitch inputs. The ground tracks did not involve any turns greater than 30 degrees and took approximately 30 minutes to fly at the conditions specified. Information on the status display was updated in response to data inputs on the MFK and aircraft position. When the NAV BOMB flight mode switch was selected, weapons information was shown on the status display in addition to the communication and navigation status and the first logic page was displayed on the MFK (Section 3.4.2.2 and Appendix E).

The pilot's flying task was to maintain groundspeed and keep the flight director symbol centered on the VSF during approximately 200 miles of flight. The pilot's keyboard task was to complete communication, navigation, and stores management tasks on the

MFK. These tasks were felt to be typical of tasks encountered on a single-seat fighter aircraft mission. The fact that both flying performance and keyboard operation performance were to be recorded was stressed to the pilots.

Each of the four missions involved the same type and number of keyboard tasks. The tasks are shown in Table 1. The data entry information and task order was randomized independently for each mission. The NAV BOMB tasks, however, were completed after the CRUISE Mode tasks with the exception of the task involving navigation mode change to TACAN which was always the final task of each flight. Mission scenarios were constructed around each set of randomized tasks in order to provide a high degree of external realism. In this way, the task orders appeared logical. The task instructions were given over the headset using standard controller terminology. (See Appendix D for task order data entry information and mission script excerpts.)

3.4.2.2 MFK Logic

Each task that the pilot was required to complete in the CRUISE flight mode involved either one task or several subtasks. Only one activation of a function select switch (either COMM for communication functions, NAV for navigation functions, or STORES for weapon functions) was required for each task. A subtask was defined as a set of specific MFK and DEK selections which logically could be considered a complete

TABLE 1

MFK COMMUNICATIONS, NAVIGATION, AND WEAPONS TASKS

TASK		NUMBER PER MISSION
1.	TASK: Change UHF Frequency (CRUISE Flight Mode)*	3
2.	TASK: Change IFF to STANDBY	1
3.	TASK: Change IFF mode in/out status	1
4.	TASK: SUBTASK: Change IFF mode & code SUBTASK: Change IFF mode STANDBY to NORMAL	1
5.	TASK: SUBTASK: Change IFF mode & code SUBTASK: Change IFF mode in/out status	1
6.	TASK: Change TACAN channel	3
7.	TASK: Add new waypoint	1
8.	TASK: Create weapon option	3
9.	TASK: SUBTASK: Change TACAN channel SUBTASK: Set course SUBTASK: Change navigation mode to TACAN	1
10.	TASK: Change UHF frequency (NAV BOMB flight mode)	1
11.	TASK: Select weapon option (NAV BOMB flight mode)	1

11 types of MFK tasks
17 tasks per mission or flight

*All tasks were performed in the CRUISE flight mode, except tasks 10 and 11, which were completed in the NAV BOMB flight mode.

task if accomplished independently. For example, an IFF mode/code change could be a complete task as could an IFF mode in/out change. When the two changes were made without an intervening activation of the COMM function select switch, they constitued subtasks. Prior to testing, the pilot was instructed that once he had started a subtask, he should complete it before starting another subtask. If the pilot did not correctly complete a subtask he was working on before he initiated another subtask, the computer ignored the selection made for the previous subtask and recognized the selections for the new subtask. In order to correctly complete the task, the pilot eventually had to redo the subtask he did not complete correctly.

Completion of each subtask required a particular operating sequence on the MFK. Each step in these operating sequences was called a logic level. Examples of the logic level sequences and specific legends are shown in Appendix E as well as a description of the operating sequence for each task type. In addition, the format of the pre-entry and status information on the MFK display is explained. The following paragraph briefly describes the operating sequence or logic levels for the tasks completed by the pilots in the experiment.

The keyboard logic used in the CRUISE flight mode, in which pilot selection of a function select switch called up pages of options appropriate to that single function, is referred to as Branching Logic (Figure 1). In the NAV BOMB flight mode, a different type of

keyboard logic or operating sequence was used. Rather than present the second level options only appropriate to the function select switch chosen, the logic used in the NAV BOMB flight mode allowed the pilot access to the second or third logic level for several functions. The options provided on the first page were options that the pilot was likely to require during the particular phase of flight selected on the flight mode switches. Controlling the MFK in this manner was called Tailored Logic (Figure 5). In order to contrast Branching and Tailored Logic, the following example is given. The Branching Logic used for the UHF communication task previously described required selection of the COMM function select switch, UHF multifunction switch on the first page from the available radios, UHF CHNG multifunction switch, digits and ENTER on the DEK. The Tailored Logic used in the NAV BOMB flight mode, however, presented immediately available options for several functions (UHF CHNG, BOMB TGT, ALT HOLD, CRS SET, WEAPON OPTION, etc.) when the NAV BOMB flight mode switch was selected. To complete a UHF change, the pilot had to select only the UHF CHNG multifunction switch, digits, and ENTER on the DEK.

3.4.2.3 Procedure

The experimenter not only had the capability to monitor the pilot's keyboard and flying performance, but was able to control the initiation of keyboard tasks and termination of test flights. A schematic representation of the procedural steps is shown in Figure 13.

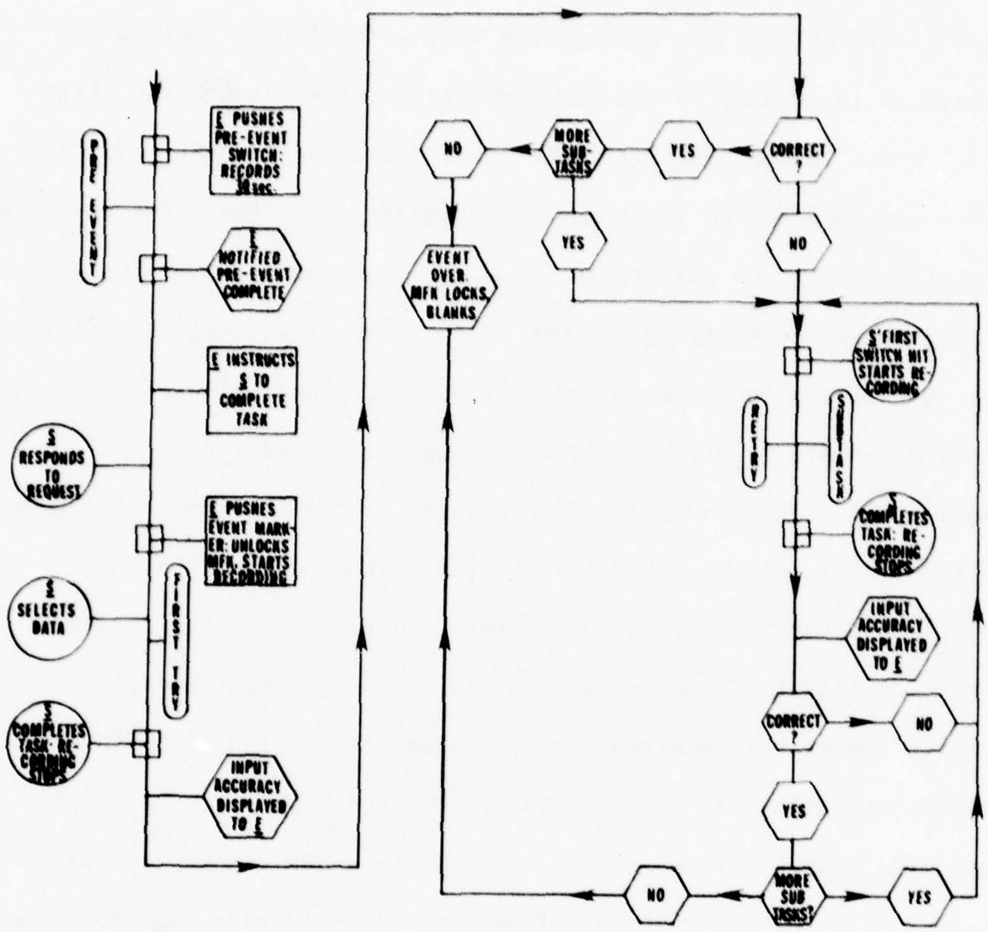


Figure 13. Schematic Representation of Procedural Steps for a Task

3.4.2.3.1 Pre-event Period of Baseline Flight Performance

The experimenter pushed a "pre-event switch" on the console which started a thirty second timer. Activa-

tion of this switch automatically designated the pre-event period of baseline flight performance recording. The pre-event switch remained lighted during the pre-event period. Concurrently, a countdown by seconds was displayed on the experimenter's status display. When the displayed countdown reached zero, the zero flashed until the experimenter initiated the task.

3.4.2.3.2 Task Event Instruction Period

Once the thirty second pre-event period of baseline performance had been recorded (pre-event switch light off, countdown "zero" flashing), the experimenter requested the pilot to complete a preprogrammed task. (Using these procedures, time to request a task or to acknowledge the instruction was not a part of the pre-event or task event time).

The experimenter followed a written script (Appendix D) to insure that each pilot received the same instructions for a particular task and mission. All the experimenter's instructions were given over the headset using standard controller terminology. The information required by the pilot to complete the tasks was provided on a modified Flight Plan (AF Form 70; Appendix D) and was referenced during the instructions by the corresponding letter, or number. For example, the UHF frequencies and IFF mode codes were identified by a letter on the Form 70. Instructions to enter waypoint

coordinates were given by the experimenter as a numerical "November point" and weapon parameter information was identified by weapon option numbers. TACAN information, however, was referenced by both the corresponding name and channel digits. By identifying the information in this way, errors due to forgetting the information were minimized.

3.4.2.3.3 Task Event Period: MFK Operation Prior to Task or Subtask Completion

Concurrent with the pilot's acknowledgment of the instructions, the experimenter pushed an "event marker switch" on the console to initiate the task. Activation of the event switch started recording of the flight parameters and keyboard operation measures and activated the appropriate MFK. Once the switch was activated, it remained lighted until the task was successfully completed.

The activation of the MFK enabled the pilot to select the appropriate options at each logic level for that particular task. Due to computer memory limitations and time constraints, only the options required for the tasks to be used in this experiment were programmed. If the pilot selected an option that was not programmed, he received the message "OPTION N/A" for that switch on the CRT or projection switch type MFK. The legend disappeared with the selection of a programmed option. To correct the mistake, the pilot pushed the correct option for that task. Mistakes made by pushing an

inappropriate programmed switch were corrected in the following manner: selecting the correct option if available on the same page or pushing the RETURN or appropriate function select switch and then selecting the correct option.

Once the pilot had progressed through the logic levels to the switch action that activated the DEK (DEK illuminated), each digit selected was displayed to the pilot. (This pre-entry readout was on the MFK in configuration 1 and on MPD 2 in configurations 2, 3 and 4.) The pre-entry readout provided the pilot with the capability to verify that the digits selected were accurate. If the pilot made an error that was in the appropriate range or realistic for the task (example: 236.7 instead of 236.6 UHF frequency), the incorrect digit(s) were displayed in the pre-entry readout (236.7). In order to correct the mistake, the pilot had to clear the incorrect digit. One push of the CLEAR key on the DEK erased the last selected digit. Two pushes of the CLEAR key erased all the digits selected since the last activation of the ENTER key. The DEK remained activated and lighted after any push of the CLEAR key.

In addition to the pre-entry readout, an error message was displayed to the pilot when an error was made that was out of the appropriate range or unrealistic for a task. For example, if 6 was selected for the first UHF frequency digit, the message "BAD DATA" was displayed to the pilot next to the preentry readout. (As a first

entry, a 6 is not in the appropriate frequency range for the UHF radio.) The actual illegal digit never appeared on the pre-entry readout, but was ignored by the computer. The DEK remained active and when the pilot made another switch hit on the DEK, the "BAD DATA" message disappeared. A second example involves the pilot selecting 21 instead of 22 as the first two digits of a UHF frequency 225.0. In this case the first digit was legal, but the second digit was out of the appropriate UHF range. Since the computer ignored the illegal digit and the first digit selected was legal, the pre-entry readout was 2 with the "BAD DATA" message displayed also. Of the first two digits, only the second digit had to be reselected.

In the case where the pilot pushed too many legal digits, the message "CHECK DATA" was displayed next to the pre-entry readout, the pre-entry readout remained except that the surplus digits were ignored by the computer, and the DEK remained active. If the remaining selected digits were the desired entry (236.7 displayed if 23677 pushed), the pilot pushed the enter button. If the desired entry was 236.6 instead of 236.7, however, the pilot had to operate the CLEAR function to erase the 7 and select 6 in order to complete the task correctly. The "CHECK DATA" message disappeared with the first hit of the CLEAR or ENTER key.

3.4.2.3.4 Task Event Period: Verification after Task or Subtask Completion

The pre-entry readout and various messages described in the previous section only pertain to the keyboard operation prior to actual completion of a task or subtask. The majority of tasks or subtasks to be used were considered complete once the pilot selected the ENTER key on the DEK. (Exceptions are noted in Appendix E.)

Once a task or subtask was completed, whether it was correct or incorrect, all recording of data stopped. If a data entry had been required as part of the task, the DEK deactivated and the preentry readout disappeared. The computer then checked to see if the data selections and entry were the same as the information programmed for the subtask. The following describes the MFK configuration and operating procedures after the computer determined whether the completed task or subtask was incorrect or correct.

a) Incorrect task or subtask completion. If a task or subtask was completed incorrectly, the pilot was required to redo it. In the case of a task with several subtasks, the pilot only had to redo the subtask that had an error. Any subtask that was previously completed correctly did not have to be redone. The subtask or task error was displayed to the experimenter on the console and the pilot's MFK remained active at the last level before subtask

completion. Note that the DEK was deactivated; if the pilot had to make a digit entry to correctly complete the retry, he had to reselect the switch on the MFK which calls up the DEK. After the pilot was notified by the experimenter over the headset that an error was made, the pilot started to redo the task or subtask; the pilot's first switch hit on the MFK of the retry initiated the recording of data. When the keyboard operation was completed again, the recording stopped and the computer verified the entry.

b) <u>Correct subtask or task completion</u>. When the computer verified that a completed subtask or task was correct, the computer then checked whether more subtasks were to be completed at that time. If another subtask was to be completed, the MFK remained activated at the last level used during the completion of the previous subtask. (The DEK was automatically deactivated at subtask completion whether correct or incorrect). The pilot's first switch hit on the MFK for the next subtask initiated data recording. In the case where no more subtasks were to be completed the MFK and the DEK became blank and deactivated, and the task was considered finished.

An exception where the pre-entry readout remained after subtask completion was when the pilot entered too few legal digits (Example: 236 for 236.7 UHF frequency). In addition, the MFK <u>and</u> DEK remained active and the message "RE-ENTER DATA" was displayed next to the readout. The pilot's first MFK or DEK switch hit of the retry initiated the recording of data and erased the message.

3.4.2.3.5 Task Abort and Flight Termination

Activation of the "ABORT TASK" switch on the experimenter's console terminated recording of a task and provided the experimenter with the capability to initialize the pre-event period for the next programmed task. This switch was only activated if the experimenter foresaw that the data being recorded was unusable and that the task would eventually have to be rerun.

After the pilot completed all the required tasks for the flight successfully, the experimenter terminated the flight by pushing the "MISSION COMPLETE" switch on the console. After the flight had been terminated, the summary statistic program was run to insure that all the data had been recorded. It should be noted that the capability existed to record data for any single task without rerunning the whole data flight. The scoring program recognized only completed blocks of data and ignored any incomplete task data.

3.4.2.3.6 Debriefing

Immediately after each flight the pilot was given a two page questionnaire concerned with the design of the activated MFK configuration and how progression through the logic implemented on the MFK configuration compared with the operation of the standard control head for each function. Following the completion

of all data flights, each pilot filled out a questionnaire designed to elicit subjective evaluations of the MFK configurations, keyboard logic, display formats, and simulation qualities. In addition, each pilot completed a form concerning his background flying experience. (See Appendix F).

3.4.2.3.7 Performance Measures and Data Analysis

The pilot's performance in terms of flying the simulator and operating the MFKs was measured. The following flight parameters were recorded two times per second on magnetic tape.

Groundspeed (knots)
Bank steering error (arbitrary units)
Pitch steering error (arbitrary units)

Appropriate summary statistics (average error, AE; average absolute error, AAE; root-mean-square error, RMS; standard deviation, SD; See Appendix G for formulae) were computed on these flight parameters for:

a) The thirty second period prior to each task event (pre-event period),

b) The time period during which the pilot correctly selected and entered information for an assigned task event.

The thirty second pre-event time was designated as baseline performance. Summary statistics for the pre-event time for each parameter were subtracted from the corresponding values computed for the time period required by the pilot to correctly complete an assigned task event. This difference score quantified the level of flying task performance during keyboard task performance.

Keyboard task performance was evaluated by measuring:

a) Keyboard operation time to correctly complete an assigned task.

b) Number of switch hits.

Since the number of required switch hits varied with task type, a switch hit index called Figure of Merit (FOM) was computed for each task by dividing the actual number of switch hits by the number required to accomplish the particular task without error. For an example computation, see Appendix G. An error-free task produced a FOM of 1.0 and as errors increased, the FOM increased. It should be noted that the selection of the NAV BOMB and CRUISE flight mode switches during the flights was not counted in the FOM, nor were the master arm switch and pickle button during the weapon release.

The flight data, keyboard operation time, and FOM were recorded on magnetic tape for each task. The data were initially analyzed by multivariate analysis of variance (MANOVA) using the BMD 12V statistical program available on the CDC 6600 computer (Reference 8). In those cases where the MANOVA revealed significant effects, subsequent analyses were conducted by stepwise discriminant function analyses (BMD 07M) in order to determine which of the dependent variables were most sensitive to changes in independent variables. The eight dependent variables which were selected for these analyses are shown in Table 2.

In the first phase of the data analysis, each type of task event completed by the pilots was examined separately. For example, the data recorded during UHF radio changes was treated apart from the data recorded during TACAN channel changes. A MANOVA of the UHF task using two types of keyboard logic (Branching and Tailored) was conducted in the second phase. Data obtained from the debriefing questionnaires was compiled to be presented in tabular form and appropriate nonparametric analyses were conducted (See Appendix G). Descriptive statistics were computed on the biographical data obtained from the flight experience questionnaire to obtain an overall view of the characteristics of the pilot sample.

TABLE 2

Summary Statistics for Each Dependent Variable

The following is a list of the summary statistics analyzed by multivariate analysis of variance and discriminant function analyses.

1.	Groundspeed (knots)	AAE
2.	"	RMS
3.	Bank steering bar (arbitrary units)	AAE
4.	"	RMS
5.	Pitch steering bar (arbitrary units)	AAE
6.	"	RMS
7.	Keyboard operation time (seconds)	
8.	Switch hits error (figure of merit)	

4. RESULTS

The results of the statistical analyses conducted on the objective performance measures are presented. (All tests conducted at α = .05). The findings of the data analyses conducted on each type of task will be given first, followed by the comparison of the UHF tasks using two types of logic. Results of the nonparametric tests performed on the subjective questionnaire data will be included in the appropriate sections of the discussion (Section 5).

4.1 PERFORMANCE DIFFERENCES AMONG CONFIGURATIONS DURING EACH TYPE OF TASK

Performance during five of the types of tasks was analyzed for each of the four MFK configurations. The tasks were: IFF, TACAN, Stores (weapon option creation), UHF, and Waypoint Load.* While the results for each of these tasks will be discussed in detail in the following paragraphs, an overview of these results is given in Table 3.

The MANOVA of the IFF tasks indicated that pilot performance significantly differed depending on the MFK configuration type used.

*Two other tasks (Weapon Option Select and Navigation Mode Changes) were not included in the analysis. Due to the nature of the tasks, the experimenter had to give directions during task completion which contaminated the data.

TABLE 3

RESULT SUMMARY TABLE FOR MFK CONFIGURATION ANALYSES

	IFF TASKS	TACAN TASKS	STORES TASKS	UHF TASKS	WAYPT LOAD TASKS
	Config. 1 2 3 4	Config. 1 2 3 4	Config. 1 2 3 4	Config. 1 2 3 4	Config. 1 2 3 4
Config. 1 Better Than	- - - -	- - - ●	- - - ●	- - - -	- - - -
Config. 2 Better Than	● - - ●	- - - ●	- - - ●	- - - -	- - - -
Config. 3 Better Than	● - - ●	- - - ●	- - - ●	- - - -	- - - -
Config. 4 Better Than	- - - -	- - - -	- - - -	- - - -	- - - -

● = $p < .05$

\- = no significant difference

($\underline{F}$ = 1.77, $\underline{df}$ = 24, 676.4, $\underline{p}$ < .05). A stepwise discriminant function analysis indicated that keyboard operation time was the dependent variable most sensitive to MFK configuration differences ($\underline{F}$ = 7.37, $\underline{df}$ = 3, 252, $\underline{p}$ <.01). Performance was significantly better with MFK configurations 2 (12.2 seconds) and 3 (12.6 seconds) than that for configuration 4 (20.1 seconds; $\underline{p}$ <.01) and configuration 1 (16.6 seconds; $\underline{p}$ <.05). See Figure 14.

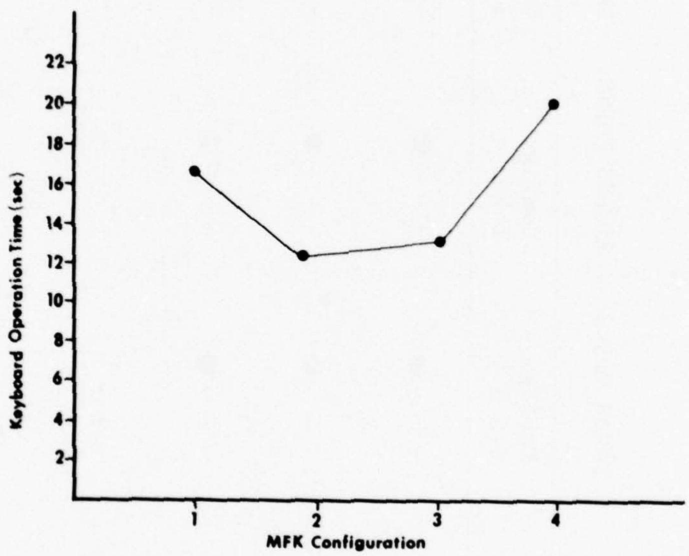


Figure 14. Mean Keyboard Operation Time Required for Completion of IFF Tasks With Each MFK Configuration Type

The four types of IFF tasks required 3, 5, 11 and 13 switch hits, respectively. A significant main effect for performance differences among these task lengths was found in this analysis ($\underline{F}$ = 7.51, $\underline{df}$ = 24, 676.4, $\underline{p}$ <.01). The absence of a significant configu-

ration by task length interaction indicated that performance with MFK configurations 2 and 3 was better than that with 1 and 4, regardless of IFF task length.

The results of the MANOVA for the TACAN channel changes also revealed that pilot performance significantly differed depending on the MFK configuration types used (F = 1.76, df = 24, 502.4, p < .05). A stepwise discriminant function analysis identified keyboard operation time again as the dependent variable most sensitive to differences between the types of MFKs (F = 9.34, df = 3, 188, p < .01). Keyboard operation time was significantly faster with MFK configurations 1 (11.4 seconds), 2 (10.3 seconds), and 3 (10.5 seconds) than with configuration 4 (14.3 seconds; p < .01; see Figure 15).

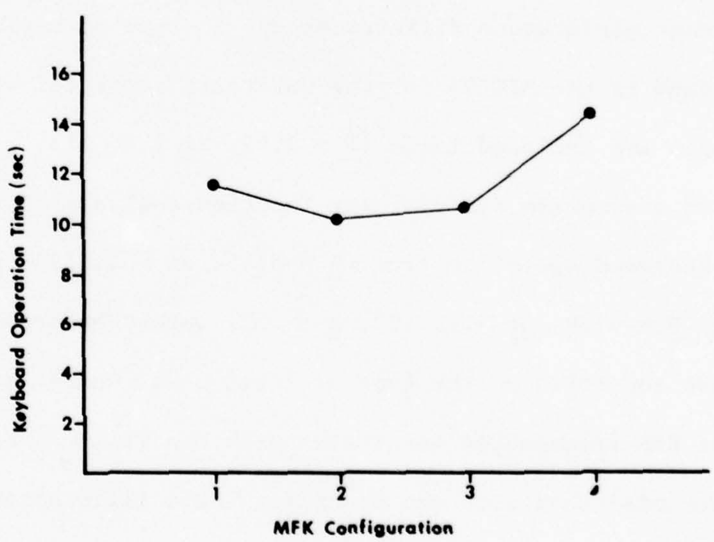


Figure 15. Mean Keyboard Operation Time Required for Completion of TACAN Channel Changes With Each MFK Configuration Type

These differences are paralleled in an analysis of the Stores task. While the data does not achieve significance at the .05 level ($F = 1.48$, $df = 24, 502.4$, $p < .10$) the trends are clearly supportive of the TACAN data. The discriminant function showed that keyboard operation time was the most sensitive variable, with configuration 4 being significantly worse than the other three configurations ($p < .01$).

Multivariate analyses of UHF frequency changes and the addition of new waypoints failed to reveal any significant differences in performance between the configurations ($F < 1$).

4.2 PERFORMANCE DIFFERENCES FOR BRANCHING AND TAILORED MFK LOGIC

Significant performance differences due to type of keyboard logic were found in the MANOVA for the UHF tasks completed with Branching Logic and Tailored Logic ($F = 2.92$, $df = 8, 113$, $p < .01$). The results of a stepwise discriminant function analysis of this data showed that keyboard operation time ($F = 5.55$, $df = 1, 123$, $p < .05$), and bank AAE ($F = 4.69$, $df = 1, 123$, $p < .05$) were the dependent variables most sensitive to the type of logic used. Operation of the MFK to change UHF frequencies was faster with the Tailored Keyboard Logic (9.6 seconds) than with the Branching Logic (11.6 seconds; Figure 16). Contrary to this finding, inspection of Figure 17, illustrating bank AAE for each type of logic, indicates that the

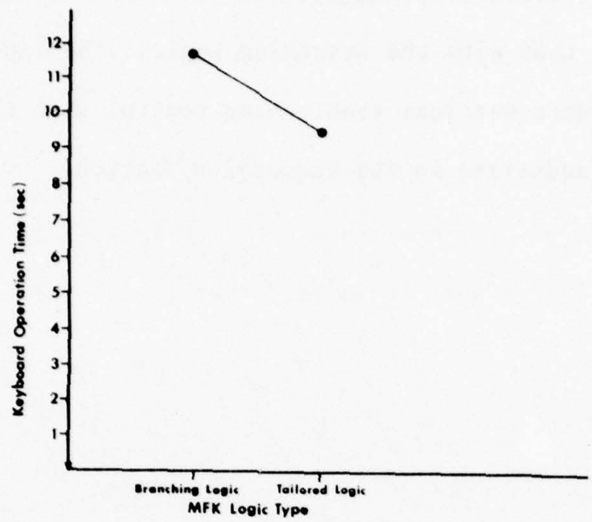


Figure 16. Mean Keyboard Operation Time Required for Completion of UHF Frequency Changes With Each Logic Type

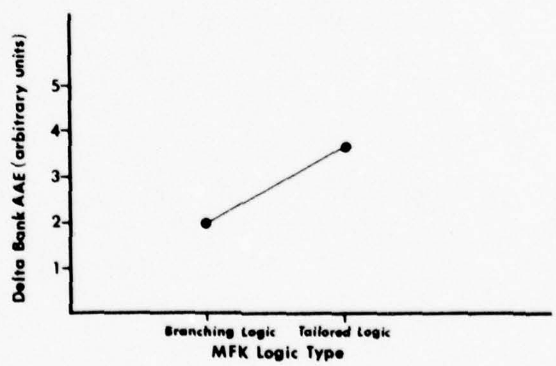


Figure 17. Delta Bank AAE for MFK Logic Type During Completion of UHF Frequency Changes

pilots had more difficulty maintaining bank with the Tailored Logic as compared to that with the Branching Logic. The implications of faster performance but less stable bank control with the Tailored Logic will be addressed in the Discussion Section.

5. DISCUSSION

In this section, the results reported in Section 4 are discussed. Findings are interpreted and explanations suggested for:

1) MFK configurations evaluted (Figure 3; Section 2.1.1) and

2) MFK logic examined

When applicable, the subjective responses of the participating pilots are referenced.

5.1 MFK CONFIGURATIONS

It is suspected that the performance differences among MFK configurations found in the operation time data were due to the additional visual search and hand motion required in configurations 1 and 4. (The MFK configuration differences were more apparent in the task types which require additional visual search and hand motion due to the way in which the logic was programmed. [See Section 5.2.1].) In both MFK configurations 1 and 4, the pilot was required to locate the desired legend on a CRT, associate the legend with the corresponding switch, and then select the switch. Moreover, some of the CRT

legends in configuration 1 were not optimally aligned with the switches for different viewing angles/seat adjustments. (Seven of the pilots commented that they experienced some difficulty selecting the switch which corresponded to the appropriate legend on the CRT MFK.) In configuration 4, the switch/legend association was even more difficult to accomplish since the CRT was spatially separated from the switches. One pilot commented that he found himself "counting the position of the information desired and then counting to determine which button to press." (The pilots also rated configuration 4 significantly worse than configurations 1, 2, and 3 on a pairwise comparison of the four configurations ($X^2 = 26.38$ $p < .01$; see Appendix G).

The results of the data analyses show that pilot performance was worse in configurations where additional search time and hand motion were required to associate legends and switches. The performance difference for configuration 1 was of smaller magnitude than that for 4, and whether the worse performance with configuration 1 was a practical difference is open to question. At the very least, the findings emphasize the importance of switch/legend alignment - if such a device is to be used, the relationship of the switch to the display _must_ be unambiguous and immediately apparent.

Pilot performance was especially poor in configuration 4 where the pilot was required to derive a spatial correspondence between the

legends on the front instrument panel and the switches on the right console. (It took the pilots 2.9 seconds longer to complete TACAN channel changes and 7.9 seconds longer to complete IFF tasks using this MFK configuration, relative to the best configuration.) Whether this is a practical difference when cockpit constraints may dictate the location and use of this hardware type remains to be determined. It is quite possible that this configuration is acceptable as a backup to a primary MFK or in high acceleration cockpit applications where front panel displays cannot be reached and side panel controls cannot be seen. These possibilities can be answered only in the context of a specific system design. But the study did provide data on the size of the performance penalty to be expected when using this type of hardware. (It should be noted that this effect was confounded with the effects of right hand location. Additional experimentation would be required if this confounding needed to be resolved or to determine the useability of this type of hardware on the left console).

The data further showed that pilot performance was better with MFK configurations in which the legend was located on the switch surface (configurations 2 and 3). The pilots commented that switch selection was easier when the legend was on the switch since no switch/legend association was required. However, one disadvantage with such hardware as implemented in this study was noted by the pilots. The task data (system status, pre-entry readout, etc.) was

separated from the MFK, whereas in configuration 1 and 4, the information was displayed on the CRT with the legends.

Concerning MFK location, the subjective data indicated that the pilots preferred that the MFK be located on the left side of the cockpit. In comparing the four configurations, the pilots rated configuration 1 (left side) better than 3 (right side) ($X^2 = 9.88$, $p < .01$) and 2 (left side) better than 3, its twin on the right side ($X^2 = 9.13$, $p < .05$). The comparison of configurations 1 and 2, both on the left side, were not significantly different. Ten of the pilots commented that they preferred that the MFK be located on the left side of the cockpit so that their right hand would be free to control the aircraft. However, in the present experiment, there was no significant degradation of flight performance when the right console MFK configurations were used. This was probably due to the relatively simple level cruise mission the pilots were required to fly. Most likely, performance differences among the configurations would occur if a more difficult flight mission was required.

5.2 MFK LOGIC

5.2.1 MFK Logic Design Considerations

A more detailed examination of the switch hits required by the logic for each task type suggests an explanation for why MFK con-

figuration differences were only observed in some tasks, and also stresses the importance of several design criteria to the optimization of MFKs. An attempt will be made to show that the configuration differences discussed in Section 5.1 are more apparent in the tasks which had additional visual search and hand motion due to the following conditions:

1) Several different subtasks were required under one task type (IFF MODE/CODE, IN/OUT, etc.) and the subtasks were randomly assigned throughout the flight.*

2) Task completion required selection of different MFK multifunction switches, rather than repeated selection of the same switch.

3) Task completion required selection of switches in nonideal locations (other than top and bottom switches of columns).

Completion of the IFF tasks involved all the above three conditions. First, the pilot's choice of switches depended upon which of the programmed functions the experimenter specified. Secondly, IFF tasks completion involved selection of different multifunction switches rather than repeated selection of the same switch; sometimes

*See Sections 3.4.2.1 and 3.4.2.2 for description of tasks and procedures used in establishing task order, etc.

a third or fourth switch hit on the MFK was required. Thirdly, only one IFF function, MODE/CODE, was in what is considered an ideal location (top key of left column). Rote learning of switch sequence and location was considered highly unlikely due to the short duration of this simulation. Thus, extensive visual search and hand motion was required in the completion of IFF tasks due to the way in which the IFF logic was programmed.

The TACAN task also required a visual search of the MFK in order to locate two different switches in nonideal locations (i.e., second and fourth on left column) prior to selecting the appropriate switch. This task differed from the IFF task in that no subtasks were required for the TACAN tasks.

The stores tasks also did not have subtasks. The stores tasks did, though, require selection of more multifunction switches: all five switches of the left column and the third switch of the right column. Most of the subject pilots accomplished the task by hitting the top left column switch first and then the second left switch and so on. This left column switch selection method may have lessened the visual search requirements for this particular task.

The absence of performance differences due to MFK configuration type in both the UHF and Waypoint Load task was most likely due to the fact that these tasks required less visual search

and hand motion. Completion of the UHF task required two successive pushes of the <u>same</u> multifunction switch. Furthermore, the required switch was located ideally (top switch of left column). Selection of two different multifunction switches was required in the Waypoint Load tasks and one of the switches was in an ideal location (top switch of the right column). The required functions for both of these tasks remained the same throughout the flights.

As can be seen in the foregoing, performance differences between MFK configurations were more apparent when task completion involved additional visual search and hand motion. Configuration differences were found in tasks where the subtasks varied throughout the flight (e.g. subtasks within IFF) and where tasks completion required selection of different MFK switches in nonideal locations (e.g., IFF and TACAN tasks). Differences among the MFK configurations were <u>not</u> found in those tasks requiring minimal visual search and hand motion (e.g., UHF task required repeated selection of an ideally located switch). These findings suggest that when logic is programmed such that the required switches are in ideal locations and switch actions involve repeated selection of the same switch, MFK operation is more efficient. Factors like these must be considered, so that the critical and frequently accomplished tasks in the single seat fighter mission can be optimally designed.

5.2.2 Branching and Tailored MFK Logic

The MFK logic might be designed and implemented in a number of ways. Two ways were examined in this simulation for the UHF tasks.* With the Branching Logic, four distinct logic steps were required to change the UHF frequency: (1) COMM function switch to call up radios, (2) UHF multifunction switch to call up UHF radio, (3) UHF CHNG multifunction switch, and (4) selection of digits and ENTER on the DEK. In the Tailored MFK Logic, the most commonly used functions for the current flight mode were automatically assigned to the switches. Rather than present the options appropriate only to a particular function after it has been selected, this logic presented the pilot with options for several functions (e.g. communications, navigation, sensors). With the logic tailored to flight mode, the UHF CHNG function was immediately available. To complete a UHF frequency change the pilot only has to select: (1) the UHF CHNG multifunction switch and (2) the digits and ENTER on the DEK.

The data showed that while radio changes could be made more rapidly using the Tailored Logic, by two seconds, there were also significant errors in control of bank. It is believed that the difficulty in maintaining bank stems from the fact that the UHF radio

*All other tasks examined in this simulation were programmed according to the Branching Logic only.

change in the Tailored Logic is a short task. It may be that the pilot rushes through a short task without reference to bank control while on the longer task, i.e. using Branching Logic, he is more likely to pause between switch activations to check flight parameters. A need for future research is indicated.

It was concluded that the design and implementation of MFK logic can have significant effects on pilot performance and that logic tailored to the flight mode produces faster operation. The fact that significant time savings can be realized on the UHF task implies that the savings on more difficult tasks may result in a considerable reduction in workload. Additionally, the pilots were quite enthusiastic about the MFK concept and indicated a preference for the Tailored Logic in their informal reactions. It is suggested that the Tailored Logic should be used as the primary logic in actual aircraft applications. The Branching Logic should also be implemented concurrently so that the pilot can access infrequently used functions not available in the Tailored Logic.

6. CONCLUSIONS AND RECOMMENDATIONS

As a result of this evaluation on multifunction keyboard (MFK) configurations and MFK logic, the following conclusions and recommendations can be made:

1. CONCLUSION: Multifunction keyboards which are designed such that the legends are displayed on the switches are optimum.

RECOMMENDATION: Because flight qualified variable legend switches are not available, and because of the lack of flexibility in changing the film for the projection switches used in this experiment, future experiments on multifunction keyboards should use the CRT display with legends adjacent to the switches (configuration 1).

RECOMMENDATION: Flight rated, Mil Spec switches, incorporating variable legends should be developed.

2. CONCLUSION: Multifunction keyboards which require an association of the switches with the corresponding legends are less than optimal.

RECOMMENDATION: If a CRT type MKF (configuration 1) is used, the legends must be aligned with the switches for the appropriate viewing angle/seat adjustment.

RECOMMENDATION: Multifunction keyboards which require the pilot to derive a spatial correspondence between the legends and the switches (configuration 4) should not be used as the primary control. Future experiments should investigate the use of such equipment as a backup MFK or as an integrated control for high acceleration cockpit applications.

RECOMMENDATION: Configuration 4 should be redesigned using switches with two levels of pressure sensitivity. The first level, e.g. 1 oz. pressure, would be activated when the pilot laid his finger on the switch. This level would cue the system as to which switch was being touched, and the proper legend on the CRT would be highlighted by a flashing asterisk. This would eliminate the requirement for the pilot to look at the switch. Pushing the switch through the second level of sensitivity, e.g. 14 oz., would be required for switch activation.

3. CONCLUSION: Multifunction keyboard operation is more efficient when the required switches are located at the top or bottom of the columns and switch actions involve repeated selection of the same switch.

RECOMMENDATION: Factors like these must be considered so that the critical and frequently accomplished tasks in the fighter mission can be optimally designed.

4. CONCLUSION: Subjective preferences indicated that the left front location for the MFK was preferred over the right console. This was not reflected in the objective data, possibly due to the simple flying task. Pilots suggested that a preferred location for a backup MFK would be aft of the throttle quadrant.

RECOMMENDATION: An evaluation of a backup keyboard aft of the throttle quadrant should be conducted.

RECOMMENDATION: Future experiments should include a more difficult flying task to increase workload to a point where differences in cockpit design can be detected in the objective data. The control laws should be degraded and/or augmented with a wind gust model in order to make the flying task more demanding.

5. CONCLUSION: Multifunction keyboard operation during UHF tasks was more efficient with the Tailored Logic than with the Branching Logic.

RECOMMENDATION: An experiment comparing Branching Logic and Tailored Logic for a variety of tasks should be conducted. Performance should also be evaluated when the two types of logic are concurrently available to the pilot.

6. CONCLUSION: Subjective evaluations of performance using MFK configurations 1 (CRT MFK-left side), 2 (projection switch MFK-left side), and 3 (projection switch MFK-right console) indicate that they are at least as good as, and probably better than standard control heads.

RECOMMENDATION: Since subjective opinion of the MFKs developed for this study indicates the possibility of a favorable comparison with standard devices we recommend they be adopted for cockpit use. However, an experiment measuring objective differences between an MFK and the standard equipment it replaces should be conducted first.

APPENDIX A

COCKPIT CONFIGURATION

1. ELECTRO-OPTICAL DISPLAYS

Four electro-optical displays were used in the present study to provide information for utilization by the pilot (Figure 4). The following describes each display in detail:

1.1 Vertical Situation Format (VSF) (See Figure 5)

A six-inch diagonal color monitor presented flight symbology to the pilot.

The horizon was indicated by the sky/ground texture. The range of the pitch scale was ± 180 degrees. Each five degree segment was indicated by lines. Each ten degree line was numbered, with a minus sign preceding the number for negative pitch angles. Not less than four, nor more than five lines, were displayed in the total field-of-view. Positive pitch angles were depicted in solid lines and negative angles were indicated by dashed lines. The pitch scales were roll stabilized. If the pitch scales coincided with any other symbol or readout, that portion of the pitch scale which interfered was blanked out.

The heading scales consisted of a moving scale and a fixed index indicating the present magnetic heading. A digital readout of the present heading, to the nearest degree, was displayed in a box. Twenty degrees either side of the index were visible at all times (40 degrees total). The scale was graduated in five degree increments and numbered each ten degrees. Total heading scale range was 0-359 degrees. When a ten degree mark moved out of the field-of-view, the digits were removed at that end. Digits were added to the scale when a ten degree mark was added to the scale. As a scale number moved into the digital readout area, it was blanked and reappeared as it moved out of the digital readout area. The heading scale and associated numerals were not roll stabilized and remained parallel to the horizontal display case axis.

The airspeed scale was graduated in 25 knot increments numbered each 50 knots and at least three sets of numbers were visible at all times. An exact readout of current airspeed was presented in the window in the center of the scale. The readout changed whenever the airspeed changed by one knot. The scale moved every one knot. The scale numerics were not superimposed over the window display, but were removed from the CRT. For the current experiment, calibrated airspeed (CAS) was displayed. The abbreviation CAS was displayed below the airspeed scale to denote airspeed was calibrated.

Barometric altitude was displayed on the altitude scale on the right side of the VSF. The scale was graduated in 250 foot increments numbered each 500 feet and at least three sets of numbers were visible at all times. The total range of the altitude scale was from minus 1000 feet to plus 99,999 feet with 1500 feet in view at all times. An exact readout of the altitude was provided in the window in the center of the scale. The readout changed whenever the altitude changed by a foot. The scale moved "continuously" in one foot increments. The scale numerics were not superimposed over the window, but were removed from the CRT when their position was within ± 150 feet of the window. When a 500 foot scale mark moved off the scale, the numerics were removed at that end. Numerical digits were added to the scale when a 500 foot mark was added to the scale as it moved. The unit's digit was not displayed. The altitude scale and associated symbols and numerics were not roll stabilized.

The bank angle scale was a fixed position scale with a variable position pointer at the bottom of the screen. The bank pointer rotated 360 degrees around the VSF but was blanked to prevent interference with other information. The scale ranged to 60 degrees either side of zero.

The flight director symbol indicated horizontal and vertical steering error information with respect to the aircraft symbol. The X, Y commands to position the flight director symbol

were such that the pilot flew the aircraft symbol to the flight director by steering the aircraft in pitch and/or bank angle.

The vertical velocity was displayed in numerical form in a fixed location in the upper right corner of the display. A caret indicated vertical velocity direction; i.e., up or down. The digital readout changed with each one foot/minute change with a range of ±9999 feet/minute.

The mach number was displayed in numerical form in a fixed location of the VSF. The digital readout changed each .01 increment of mach up to mach 2.

When any digit changed on the display faster than two times/second (i.e., vertical velocity) that digit was displayed as zero.

1.2 Horizontal Situation Format (HSF) (See Figure 6)

A seven inch monitor presented simplified navigation information in a track-up format. A map corresponding to a vertical distance on the HSF of approximately 80 miles was used.

The aircraft's true track was displayed at a fixed location centered at the top of the HSF. The value displayed ranged from 0-359 degrees.

The true track of the next waypoint after reaching the waypoint being flown to was displayed in the upper left corner as indicated in the figure with an "N" preceding the value of the track.

The fuel quantity was displayed in the fixed location below the next track angle in the upper left corner of the HSF. Fuel quantity was displayed with an "F" preceding the digital readout of the remaining fuel in pounds; e.g., F 17500.

The range scale was displayed in the upper right corner of the HSF and indicated the range covered by the map in nautical miles measured vertically.

The distance to go to the next waypoint and the time to go to the next waypoint were displayed in the lower left corner of the HSF. The waypoint identifier was given, followed by the distance in nautical miles and the time to go to the nearest tenth of a minute.

The time and distance to the next target was displayed in the lower right hand corner.

The groundspeed was displayed continuously below the range scale to the nearest knot. Display of groundspeed was preceded by the alphabetical characters GS; e.g., GS 461.

The crosstrack deviation was displayed on the HSF by the relative displacement of the track line on the map from the aircraft symbol. In the true track-up mode, the aircraft was positioned in the center of the display, but only about 1/5 of the way up from the bottom. The map moved while the aircraft remained fixed in position. The map moved under the aircraft symbol and was positioned to show the actual aircraft position in relation to the desired track.

The waypoint symbol and its identification (ID) was displayed anytime that waypoint was on the map. Each waypoint had an ID, which was its numerical designation.

1.3 Multifunction Display (MPDs)

Two six inch diagonal black and white monitors displayed mission related data to the pilot. In MFK configurations 2, 3, 4, MPD 1 (upper right front panel) displayed communication and navigation data during the CRUISE flight mode (Figure 7) and the same information plus stores data during the NAV BOMB flight mode (Figure 8). MPD 1 was blank in MFK configuration 1. MPD 2 (lower right front panel) displayed the format just described in MFK configuration 1. When MFK configuration 2 or 3 was activated, MPD 2 displayed pre-entry task information (Figure 9). This consisted of a task identifier (e.g. UHF CHNG or IFF MODE/CODE, and appeared in the same relative position on MPD 2 as they appeared on the CRT in configura-

tion 1 or 4), selected digits, and any error messages. MPD 2 displayed the multifunction switch legends in MFK configuration 4.

3. DEDICATED DISPLAYS AND CONTROLS

Most of the backup flight instruments in the cockpit simulator were inoperable so that the pilot was forced to use the information displayed on the VSF and HSF to maintain control of the aircraft simulator. However, the following instruments, switches and indicators were operable and available for use by the pilot:

a. Angle of Attack (AOA). The AOA indicator operated through a range from 0 through 30 units. The off flag functioned normally.

b. Pitch Trim Knob (left console). Adjusted the alignment of the horizon line with the aircraft symbol on the VSF.

c. Master Arm Switch. Had to be in the arm position in order to deliver weapons.

d. Stick Switches. Trim button adjusted stick to neutral position. Bomb release button enabled a weapon option to be released.

e. Flight Mode Switches (upper center front panel; Figure A1). Only the CRUISE and NAV BOMB flight mode switches were operable. The

selected flight mode switch determined the information displayed on MPD 1. Selection of the NAV BOMB flight mode switch called up the Tailored Logic format on the MFK (See Appendix E).

Engine instrumentation was provided independently of the DAIS system.

f. RPM. Indicated engine speed in percent RPM. The instrument was calibrated from 0 - 100%. The normal operating range was 52 - 100%.

g. Turbine Outlet Pressure (TOP). TOP was used as an indication of engine performance. Calibrated in inches of mercury, the operating range was 25 - 45 in Hg.

h. Fuel Quantity. Indicated total usable internal fuel, ranging from 0 - 9,000 lbs.

i. Turbine Outlet Temperature (TOT). Indicated TOT in degrees C (pointer and digital readout). The usable range was 0 - 1000 degrees C. The off flag functioned normally.

j. Oil Pressure. Indicated engine oil system pressure in psi. The instrument was calibrated 0 - 60 psi with a normal operating range of 27 - 53 psi.

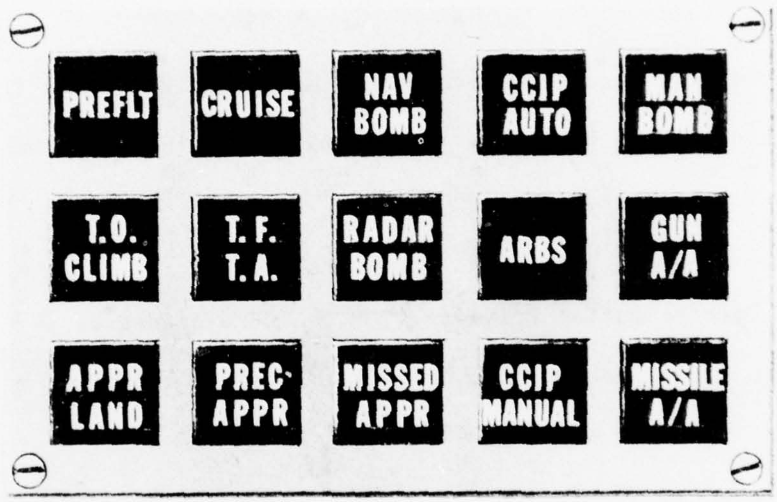


Figure A1. Flight Mode Switches

APPENDIX B

EXPERIMENTER'S CONSOLE AND SIMULATOR FACILITIES

1. EXPERIMENTER'S CONSOLE

The console was equipped with CRT displays and status light matrices which provided the experimenter with the capability of monitoring the displays in the simulator and the actual switch actions (Figure 10). A layout of the experimenter's console is shown in Figure B1. The following list specifies the functions allocated to each piece of equipment on the console that were used in the present study. Each letter refers to the notations used on the layout.

A = Status display (Figure B2); display of flight and task event information

B = Repeater display of multifunction switch legends on the MFK

C = Repeater display of MPD 2

D = Repeater display of MPD 1

E = Repeater display of HSF (map)

F = Repeater display of VSF

G = Master power switch for facility

H = Abort switch for McFadden flight control system

I = Interphone option selections (Note: the pilot's mike is always hot.)

J = On/off switch for interphone system

K = Switch enabled communication between two experimenters

L = Switch enabled experimenter/pilot communication

M = Switch enabled experimenter/computer personnel communication

N = Switch enabled communication between experimenters, pilot and computer personnel

O = Headset jack input

P = Volume control for headset

Q = Voice recorder

R = Run switch for voice recorder

S = Pause switch for voice recorder

T = Reset switch for McFadden system

U = Pre-event switch; activation initiated thirty seconds of flight data recording

V = Event marker switch; activation unlocked MFK, started recording of task event data

W = Mission complete switch (guarded); activation terminated test flight

X = Run switch for simulation

Y = Indicated whether tape recording was continual or voice activated

Z = Hold switch for simulation

A1 = Task abort switch (guarded); activation terminated recording of task event data and initialized MFK for next task event

A2 = Indicated whether left or right DEK activated

A3 = Indicated whether left front panel or right console function select switches activated

A4 = Indicated whether left front panel or right console multifunction switches activated

A5 = Indicated whether left front panel or right console projection switch MFK was activated

A6 = Indicated whether lamps were on or off for the projection switch MFK activated

A7 = Volume control for headset

A8 = Headset jack input

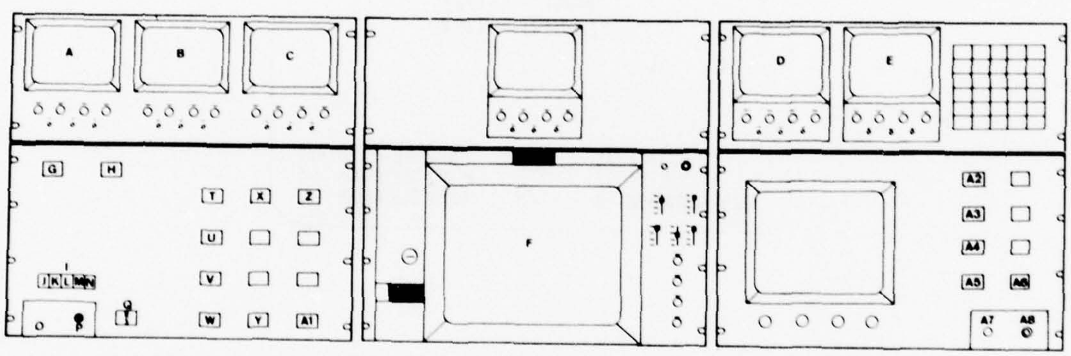


Figure B1. Layout of the Experimenter's Console.

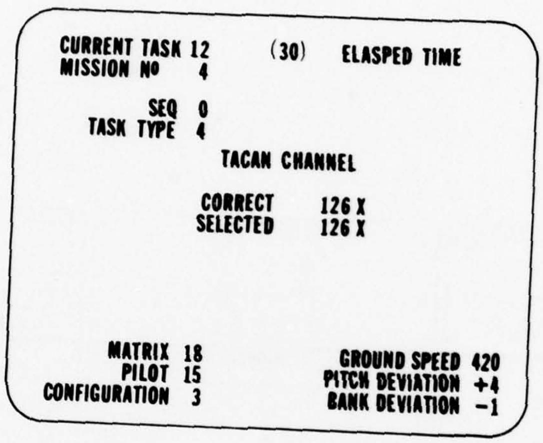


Figure B2. Status Display on the Experimenter's Console.

2. SIMULATOR FACILITIES

The simulator consisted of interconnected facilities as shown in Figure B3. A functional description of each system element is provided below.

a. PDP 11/50

Configuration Control - used to set up the cockpit controls/ displays configuration prior to each flight.

Display Assembly - generated image listings to be further processed by the Ramtek raster symbol generator. Data from the simulation models was used for the VSF and MPD formats.

Map Driver - provided output control of map data to the Ramtek symbol generator.

Keyboard Logic - processed incoming switch data and determined the display state of all the keyboards.

Flight Control Sampling and Scaling - buffered and scaled flight control data to be used by simulation models.

Simulation Models - provided all necessary aircraft parameters to be used in display processing.

Data Recording - recorded cockpit display parameter data on magnetic tape.

Data Reduction - an off-line program reduced the raw real-time recorded data into meaningful data that could be analyzed.

b. Ramtek

Display Generation - processed image lists to display VSF, HSF, and MPDs on 525 line raster monitors. Color and black/white display generators were used.

c. Cockpit

Keyboard Input/Output - provided a switch image buffer of all cockpit switch states to be sampled by the 11/50. Also decoded keyboard display data being sent from the 11/50.

Flight Control - Digitized analog stick, rudder, and thrust control inputs and buffered the resultant data for transmission to the 11/50.

d. Support Equipment

Console Terminal - system operators input/output device to the 11/50.

Printer and Card Reader - hard copy input/output to the 11/50.

Disk Drive - mass storage device for the operating system.

Magnetic Tape Drive - mass storage device for data collection.

Discrete and Analog Input/Output - input/output port from the 11/50 to all cockpit and experimenter consoles' subsystems.

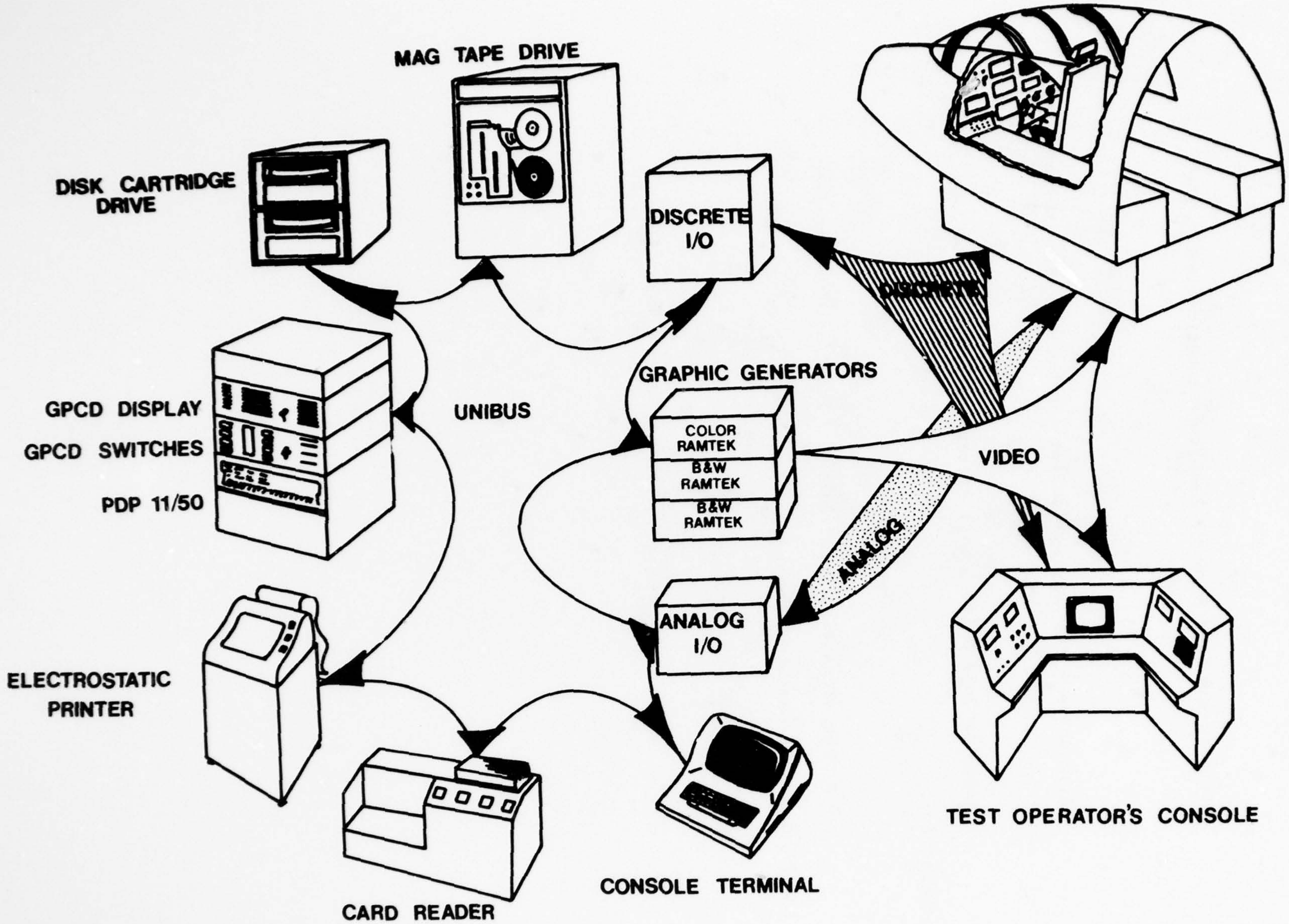


Figure B3. Simulator Facility Configuration.

APPENDIX C

DAILY TEST SCHEDULE

The following daily test schedule indicates the time and activity to train, test, and debrief one pilot during one day of the experiment. Times for controls/ displays familiarization, training flight, test flights, simulator reconfigurations, data verification, and debriefing are indicated in the schedule provided. As was mentioned in paragraph 3.4.1, each pilot participated in a three hour briefing at his home base prior to the on-site testing.

AD-A066 140 BUNKER-RAMO CORP WRIGHT-PATTERSON AFB OH F/G 5/9
MULTIFUNCTION KEYBOARD IMPLEMENTATION STUDY.(U)
DEC 78 R P BATEMAN, J M REISING, E L HERRON F33615-76-C-0013
UNCLASSIFIED AFFDL-TR-78-197 NL

2 OF 3
AD
A066140

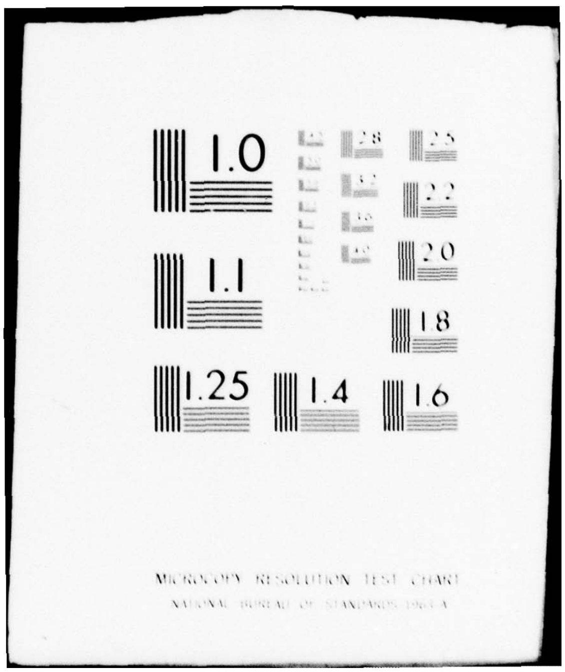

1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE C1

DAILY TEST SCHEDULE

Day 1

Time	Activity*
0900 - 1000	Cockpit briefing
1000 - 1030	Training flight
1030 - 1045	Simulator reconfiguration
1045 - 1115	Data Flight 1
1115 - 1130	Pilot completion of short questionnaire Flight 1 Data Verification Simulator reconfiguration
1130 - 1200	Data Flight 2
1200 - 1215	Pilot completion of short questionnaire
1215 - 1315	Lunch Flight 2 Data Verification Simulator reconfiguration
1315 - 1345	Data Flight 3
1345 - 1400	Pilot completion of short questionnaire Flight 3 Data Verification Simulator reconfiguration
1400 - 1430	Data Flight 4
1430 - 1445	Pilot completion of short questionnaire Flight 4 Data Verification
1445 - 1630	Pilot completion of final questionnaire Debriefing

*See Section 3.4 for description of each activity.

APPENDIX D

FLIGHT INFORMATION

A total of five missions, four for test flights and one for the training flight were used in the experiment. Initial conditions for all the missions are specified in Table D1. The task order and data entry information for each mission are provided in Table D2. As a sample, the symbolic map (Figure D1), Flight Plan (modified AF Form 70; Figure D2), and script excerpts (Table D3) for mission 3 are included.

The cockpit was in the following configuration at the initialization of each flight:

a) Flight mode switches - CRUISE flight mode switch activated.

b) VSF - Flight parameters appropriate to that of level flight in a cruise mode with an altitude of 6,000 feet and calibrated airspeed of 383 knots.

c) HSF - Aircraft position on track, approximately fifteen miles short of the first waypoint. Heading same as that for the first leg. Groundspeed of 420 knots and fuel amount of 7093 pounds.

d) MPD 1 (upper right front panel) - CRUISE format consisting of communication and navigation status information in MFK configurations 2, 3, and 4 and blank in MFK configuration 1.

e) MPD 2 (lower right front panel) - Blank in MFK configurations 2, 3, and 4 and the CRUISE format in MFK configuration 1.

f) MFK - inoperative

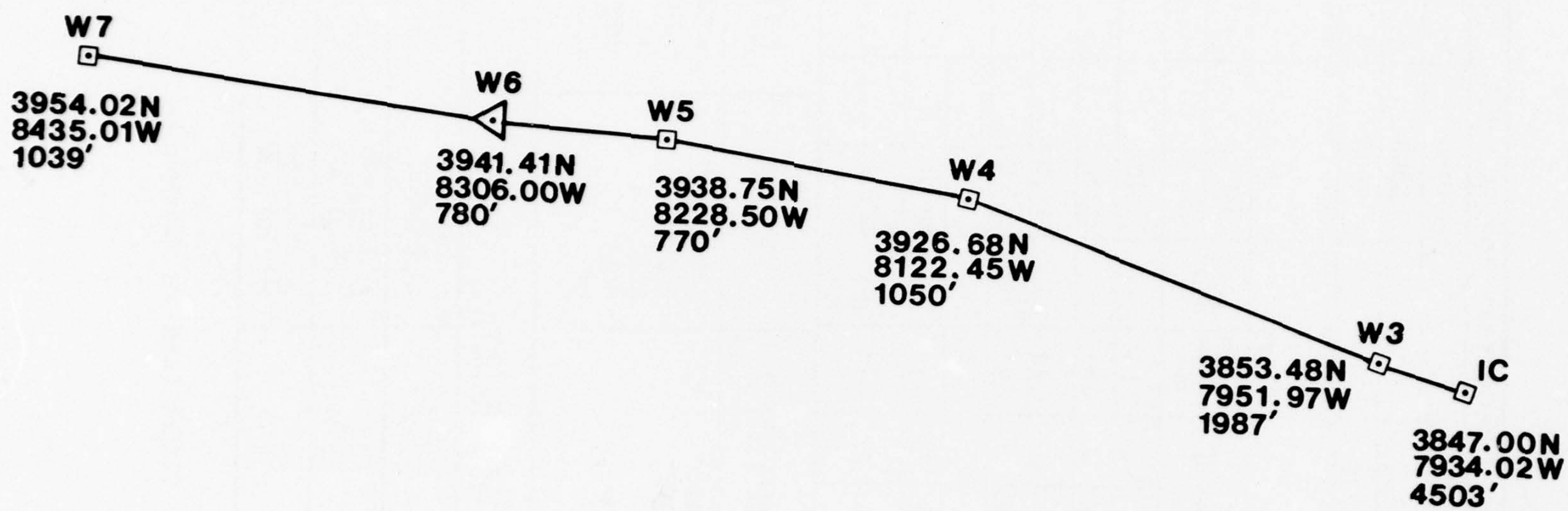

W7
3954.02N
8435.01W
1039'
W6
3941.41N
8306.00W
780'
W5
3938.75N
8228.50W
770'
W4
3926.68N
8122.45W
1050'
W3
3853.48N
7951.97W
1987'
IC
3847.00N
7934.02W
4503'

Figure D1.

PILOT'S FLIGHT PLAN AND FLIGHT LOG	UHF			MODE 3 CODE	
ARTC FREQ	A 297.3	D 267.6		P 6700	S 2700
	B 244.9	E 288.2		Q 5600	T 5200
	C 237.6	F 238.2		R 6500	U 3300
AIRCRAFT IDENT		TAKE-OFF TIME	TOTAL DISTANCE	TOTAL ETE	TOTAL AMT FUEL
CHEROKEE			175	25:00	

FIX	ROUTE	IDENT / FREQ	IDENT / FREQ	MAG CRS	DISTANCE / REMAIN	GROUND SPEED	ETE / REMAIN	ETA / ATA	LEG / REMAIN	ACTUAL FUEL REMAIN
#3	3853.48N		ELK	296	15	420	02:10			
	7951.97W		115X		160		22:50			
#4	3926.68N		PKE	295	78	420	11:10			
	8122.45W		101X		82		11:40			
#5	3938.75N		HID	283	53	420	07:30			
	8228.50W		120X		29		04:10			
#6	3941.41N			275	29	420	04:10			
	8306.00W				--		--			

OPTION 1	OPTION 2	OPTION 3	OPTION 4
18MK82 PAIRS ALL 75FT NT	12MK82 PAIRS ALL 50FT NT	10MK82 PAIRS ALL 90FT NT	14MK82 PAIRS ALL 60FT NT

NOVEMBER DATA

1.	3821.29N / 8208.93W	MAL / 118X	4.	3855.13N / 8409.45W	RUS / 123X
2.	3954.02N / 8435.01W	MAN / 111X	5.	3851.89N / 8101.00W	NOR / 104X
3.	3822.35N / 8124.30W	KAN / 110X	6.	3838.66N / 8301.23W	ORK / 112X

Figure D2. Flight Plan for Mission 3.

TABLE D1. Initial Conditions for Each Mission.

	TRAINING MISSION	MISSION ONE	MISSION TWO	MISSION THREE	MISSION FOUR
LOCATION	3708.50N 8342.30W	3640.25N 8342.00W	3932.35N 7921.96W	3847.00N 7934.02W	3855.13N 8350.55W
HEADING	109^{o}	033^{o}	248^{o}	296^{o}	112^{o}
GROUND SPEED	420KTS	420 KTS	420 KTS	420 KTS	420 KTS
ALTITUDE	6,000 FT	6,000 FT	6,000 FT	6,000 FT	6,000 FT
UHF	T/R & G Pres. 340.3 Prev. 357.8	T/R & G Pres. 337.8 Prev. 236.6	T/R & G Pres. 263.1 Prev. 341.2	T/R & G Pres. 297.3 Prev. 245.3	T/R & G Pres. 359.0 Prev. 362.9
TACAN	T/R Pres. 107X Prev. 104X	T/R Pres. 107X Prev. 126X	T/R Pres. 116X Prev. 121X	T/R Pres. 105X Prev. 119X	T/R Pres. 121X Prev. 110X
IFF	Normal Mode 1 Code 41 Mode 2 Code 1500 Mode 3 Code 5500	Normal Mode 1 Code 27 Mode 2 Code 0111 Mode 3 Code 1400 Mode 3 Out	Standby Mode 1 Code 08 Mode 2 Code 3500 Mode 3 Code 5900	Normal Mode 1 Code 63 Mode 2 Code 5200 Mode 3 Code 3300 Mode 3 Out	Normal Mode 1 Code 49 Mode 2 Code 4400 Mode 3 Code 7300
IMS	Normal	Normal	Normal	Normal	Normal
WEAPON	10 MK 82 PR ALL 70 FT NT	2 MK 82 PR ALL NT	14 MK 82 PR ALL 75 FT NT	18 MK 82 PR ALL 75 FT NT	10 MK 82 PR ALL 50 FT NT
FLIGHT MODE	CRUISE	CRUISE	CRUISE	CRUISE	CRUISE

85

TABLE D2. TASK ORDER AND DATA ENTRY INFORMATION*

TASK	TRAINING - Z		MISSION 1 - A		MISSION 2 - B		MISSION 3 - C		MISSION 4 - D	
1	WPT 8 (N 3)	362095 N 783567 W	UHF	D 348.0	IFF 3	T 3/3600	WPN	Q 12 OPT I 50 2	WPN	Q 12 OPT I 50 2
2	WPN	Q 16 OPT I 90 2	IFF 4	Q 3/2100 IN - 3	UHF	C 303.4	IFF 4	P 3/6800 IN - 3	IFF 1	STBDY
3	UHF	F 296.7	TCN	HAZ 115X	IFF 2	DE - 1	TCN	ELK 115X	UHF	A 359.0
4	WPN	Q 12 OPT I 80 4	WPT 9 (N 1)	394970 N 802260 W	WPT 8 (N 4)	360807 N 811225 W	IFF 1	STBDY	TCN	YRK 110X
5	IFF 1	STBDY	UHF	E 241.9	TCN	CLK 125X	WPT 7 (N 2)	395402 N 843501 W	WPN	Q 16 OPT I 90 3
6	TCN	BSG 126X	TCN	PSB 104X	WPN	Q 18 OPT I 40 2	UHF	D 267.6	WPT 9 (N 5)	364998 N 793930 W
7	WPN	Q 18 OPT I 60 3	UHF	C 255.9	IFF 4	S 3/4100 IN - 1	TACAN	PKE 101X	IFF 3	Q 3/4800
8	IFF 3	P 3/3000	IFF 1	STBDY	UHF	A 231.5	UHF	E 288.2	TCN	LES 124X
9	TCN	SGV 110X	WPN	Q 16 OPT I 90 2	UHF	E 367.8	WPN	Q 10 OPT I 90 3	WPN	Q 18 OPT I 70 4
10	UHF	A 333.6	WPN	Q 12 OPT I 50 3	IFF 1	STBDY	TCN	HID 120X	UHF	B 274.9
11	TCN	ELK 108X	TCN	KAN 112X	WPN	Q 16 OPT I 90 3	IFF 2	DE - 1	TCN	MAL 118X
12	IFF 4	Q 3/5400 DE -1	IFF 3	T 3/3700	WPN	Q 12 OPT I 50 4	WPN	Q 14 OPT I 60 4	IFF 2	DE - 1
13	IFF 2	IN - 1	IFF 2	DE - 1	TCN	GAS 118X	IFF 3	S 3/2700	IFF 4	T 3/4200 IN - 1
14	UHF	C 387.4	WPN	Q 18 OPT I 75 4	TCN	BEC 100X	UHF	C 237.6	UHF	D 364.0
15	N B OPT	3	N B UHF	A 253.8	N B OPT	2	N B OPT	1	N B UHF	E 350.7
16	N B UHF	E 263.1	N B OPT	4	N B UHF	D 2942	N B UHF	F 2382	N B OPT	4
17	TCN N/M	T - 105X C - 089	TCN N/M	T - 106X C - 025	TCN N/M	T - 122X C - 179	TCN N/M	T - 111X C - 281	TCN N/M	T - 108X C - 147

*See Section 3.4.2.1 for additional information.

TABLE D3

EXCERPTS FROM MISSION THREE SCRIPT*

CHEROKEE ZERO ONE, PLAYBOY ON ALPHA FREQUENCY.

ROGER, CHEROKEE ZERO ONE, BEACON TRAFFIC, 1 O'CLOCK, 2 MILES SHOULD BE 2000 HIGH

TASK 1 (OPT 2, Q12, I50)

CHEROKEE ZERO ONE, PLAYBOY. REQUEST YOU PROGRAM AND SAVE WEAPON OPTION 2.

CHEROKEE ZERO ONE, PLAYBOY. CONFIRM WEAPON OPTION 2 SAVED.

. . .

TASK 5 (WPT 7, N2, 395402N, 843501W)

CHEROKEE ZERO ONE, PLAYBOY. I HAVE A MISSION CHANGE FROM BLUE CHIP.

*See Section 3.4.2.1 for description of script use.

. . .

INSERT NOVEMBER POINT TWO AS WAYPOINT 7.

CHEROKEE ZERO ONE, PLAYBOY. CONFIRM MISSION CHANGE; NOVEMBER POINT 2 NOW WAYPOINT 7.

. . .

TASK 6 (D 267.6)

CHEROKEE ZERO ONE, PLAYBOY. CONTACT PYRAMID ON DELTA FREQUENCY. PYRAMID ON DELTA.

ROGER, CHEROKEE ZERO ONE, PYRAMID READS YOU LOUD AND CLEAR. HOW ME?

ROGER, ZERO ONE, CONTINUE ENROUTE, MAINTAIN LISTENING WATCH THIS FREQUENCY.

. . .

TASK 10 (HID 120X)

CHEROKEE ZERO ONE, ALLEY CAT. REQUEST YOU TUNE YOUR TACAN TO HIDE-A-WAY, CHANNEL 120X.

CHEROKEE ZERO ONE, ALLEY CAT. BE ADVISED OUR RADAR SHOWS YOU CROSSING FEBA AT THIS TIME, ACKNOWLEDGE.

. . .

TASK 13 (S 2700, NORM)

CHEROKEE ZERO ONE, ALLEY CAT. SQUAWK MODE NORMAL CODE SIERRA.

CHEROKEE ZERO ONE, ALLEY CAT. COPY YOUR SQUAWK.

NAV BOMB

ROGER, ZERO ONE, SELECT NAV BOMB FLIGHT MODE CONTINUE ON COURSE, STANDBY FOR TARGET DATA

. . .

TASK 15

CHEROKEE ZERO ONE, SKYSPOT, LATEST RECCE DATA PLACES YOUR TARGET AREA IN THE CENTER OF A DEEP LOW. CEILING LESS THAN 1000 FEET, VISIBILITY 1/2 MILE RAIN, WINDS LIGHT AND VARIABLE

CHEROKEE ZERO ONE, SKYSPOT, WITH WEAPONS ASSIGNMENT. READY TO COPY, SIR?

ROGER, ZERO ONE, SELECT WEAPONS OPTION 1 FOR YOUR TARGET. ACKNOWLEDGE WEAPONS OPTION 1 FOR TARGET 6.

. . .

APPENDIX E

KEYBOARD LOGIC AND DISPLAY FORMAT FOR TASKS

1. OPERATING SEQUENCE FOR EACH TASK TYPE

In the CRUISE flight mode, the operating sequences involved pilot selection of a function select switch which called up logic pages of options appropriate to that single function.

<u>Change UHF Frequency</u>

The pilot selected the COMM function select switch, UHF and UHF CHNG multifunction switches, 4 digits and ENTER on the DEK.

<u>Change IFF to STANDBY</u>

The pilot selected the COMM function select switch, IFF and STANDBY multifunction switches. Once the STANDBY switch was pushed, the task event was considered complete.

<u>Change IFF Mode In/Out Status</u>

The pilot selected the COMM function select switch, IFF and MODE IN/OUT multifunction switches, 1 digit and ENTER on the DEK.

Change IFF Mode and Code and Change IFF from STANDBY to NORMAL

First, the pilot selected the COMM function select switch and the IFF multifunction switch. To change an IFF mode and code, the pilot selected MODE/CODE multifunction switch, 1 digit, ENTER, four digits, and ENTER. To change IFF from STANDBY to NORMAL the pilot pushed the NORMAL multifunction switch. The pilot could complete the two subtasks (changing IFF mode and code and changing IFF from STANDBY to NORMAL) in either order. Once the ENTER key was pushed the second time (or the NORMAL switch), the task event was considered complete.

Change IFF Mode and Code and Change IFF Mode In/Out Status

The pilot first selected the COMM function select switch and the IFF multifunction switch. To change the code, the pilot selected MODE/CODE multifunction switch, 1 digit, ENTER; to change the mode he selected 4 digits and ENTER on the DEK. To change the mode in/out status, the pilot selected the MODE IN/OUT multifunction switch, 1 digit and ENTER on the DEK. The pilot could complete the two subtasks (changing mode in/out status, and changing mode and code) in either order.

Change TACAN Channel

The pilot selected the NAV function select switch, TCN and TCN CHNG multifunction switches, 3 digits, "X" and ENTER on the DEK.

Add New Waypoint

The pilot selected the NAV function select switch, DATA ENTRY and WAYPOINT LOAD multifunction switches, 1 digit (waypoint number), ENTER, 6 digits and alphanumeric (latitude), ENTER 6 digits and alphanumeric (longitude), 2 ENTERS. The task event was considered complete once the ENTER key was pushed two times consecutively. The pilot could complete the latitude and longitude digit entries in either order.

Create a Weapon Option

First the pilot selected the STORES function select switch and the "MK 82" multifunction switch. Next, the pilot selected several weapon parameters shown below. The selection could be completed in any order.

Quantity - Pilot selected the QUANTITY multifunction switch, 2 digits and ENTER on the DEK.

Single/Pairs - Pilot pushed the SINGLES multifunction switch to select PAIRS.

Interval - Pilot selected the INTERVAL multifunction switch, 2 digits and ENTER on the DEK.

Fuze Selection - Pilot selected the FUZE NOSE multifunction switch.

Fuze Selection - Pilot selected the FUZE TAIL multifunction switch.

After the pilot had completed selection of these parameters he selected the SAVE multifunction switch, a digit which designated a location in memory and ENTER on the DEK.

Change a TACAN Channel, Change Nav Mode to TACAN, and Set a Course

First, the pilot selected the NAV function select switch. To change the TACAN channel, the pilot selected TCN and TCN CHNG multifunction switches, 3 digits, "X", and ENTER on the DEK. To change the navigation mode to TACAN, the pilot selected the NAV MODE and TACAN multifunction switches. To set the course, the pilot selected TCN (unless already in the TCN logic), CRS TO multifunction switch, 3 digits, and ENTER on the DEK. The pilot could complete the navigation mode change either before or after the other two subtasks. Once the ENTER key was hit the second time (or TACAN was selected, depending on the subtask order), the task event was considered complete.

In the NAV BOMB flight mode, the Tailored Logic was used which allowed the pilot access to the second or third logic level for

several functions. The pilot was required to complete the following two tasks events in the NAV BOMB flight mode using the Tailored Keyboard Logic.

Change UHF Frequency

The pilot selected the UHF CHNG multifunction switch, 4 digits and ENTER on the DEK.

Select Weapon Option

The pilot selected the weapon option switch corresponding to the option number desired. This activated the particular option.

No mention has yet been made that the pilot was sometimes required to return to a previous page in the operation sequence. To accomplish this, activation of the RETURN switch on the MFK called up the previous page and activation of the function select switch called up the first page under that function.

2. MFK DISPLAY FORMAT

2.1 Mechanization

Today's pilot has access to a multitude of information concerning the status of various aircraft subsystems and associated

controls. In most cases, he may look at a particular control head and determine whether the system is on or off, what operating mode is selected and what frequency or code is set. Access to information will not be lost with the advent of multifunction switching and programmable displays. On the contrary, as much or more information will be available to the pilot and it will be centralized in location. The status of most of the systems was displayed on a MPD (see paragraph 2.2.1 for CRUISE and NAV BOMB flight mode formats). In addition, status and pre-entry information was displayed separate from the MPD when the pilot proceeded through the logic steps. This information consisted of previous and current frequencies and channels, IFF mode/ code data, etc., as well as a pre-entry readout of all digits selected before they are entered into the system.

This status and pre-entry information was displayed on the CRT format in MFK configurations 1 and 4 and on MPD 2 in MFK configurations 2 and 3 which involved the projection switch type hardware. The information appeared in the same relative position on MPD 2 in configurations 2 and 3 as they appeared on the CRT format in configurations 1 and 4.

Two conventions were employed in presenting digital information to the pilot whether it consisted of current or pre-entry data. The differences in conventions were related to the type of task event and are illustrated in the case of the CRT MFK configuration. If a

task event required only one activation of the DEK ENTER key; e.g., UHF change, the information was presented to the pilot under the appropriate CRT MFK legend adjacent to the multifunction switch. If two or more activations of the ENTER key were required, e.g., inserting a waypoint, the data was presented in the center column of the CRT MFK, with each new piece of data written on a separate line. Current frequencies, channels, IFF squawks, weapon selections, waypoint coordinates, etc. were presented to the pilot according to these guidelines. In addition, the previous frequency/channel for UHF/TACAN was displayed in the center column of the CRT MFK.

When the DEK was activated, the multifunction switch legend which called up the DEK had an asterisk displayed by it in MFK configurations 1 and 4 and was backlighted green in configurations 2 and 3. The pilot was presented with a readout of all digits selected on the DEK before pushing the ENTER key. He could use this pre-entry readout to verify that the digits selected were correct and sequenced properly. In the case of a single unit data input, e.g., UHF CHNG, the pre-entry readout was written over the current frequency beneath the appropriate legend on the MFK. This pre-entry readout convention applied to UHF changes, TACAN changes and the tailored tasks exercised in the NAV BOMB flight mode. When the pilot had to activate the ENTER key two or more times during a task, e.g., adding a waypoint, the pre-entry readout was written over the corresponding current data located on the CRT MFK center column. This convention

applies to Waypoint Loads, IFF Mode/Code changes and Weapon Option selections.

When the pilot selected the first digit on the DEK, the current data display for that particular subtask was erased. For example, selection of the first digit in a UHF change task completely erased the display of the frequency. During a Waypoint Load task, each line was erased as the first digit appropriate to that line was selected on the DEK. When the ENTER key was pushed, the data was entered into the system, the digits indicated current status, and in the case of UHF and TACAN, the "previous" information in the MFK center column was changed as appropriate.

The IFF mode IN/OUT function required special treatment. Though not a digital pre-entry readout, a method was employed which allowed the pilot to verify the mode which was activated or deactivated. To deactivate Mode 3, the pilot selected COMM, IFF and mode IN/OUT on the MFK and 3 on the DEK. When 3 was selected, parentheses appeared around the Mode 3 readout on the MFK center column to indicate the mode which would be affected. When the ENTER key was activated, the parentheses remained in position around the Mode 3 readout as a reminder to the pilot that he was not squawking Mode 3. To activate Mode 3, the pilot followed the same sequence described above and when he selected 3 on the DEK, the parentheses around the Mode 3 blanked. As soon as the ENTER key was activated, the absence of parentheses indicated that Mode 3 was squawking.

The pilot could switch back to a previous UHF frequency or TACAN channel without selecting any digits. The "previous" information displayed in the MFK center column was saved in the computer memory and the pilot could change to that frequency/channel by selecting COMM, UHF, UHF CHNG and ENTER for the UHF frequency or NAV, TCN, TCN CHNG and ENTER for the TACAN channel. It is important to note that it was not possible to continue to go back to earlier selected frequencies/channels. Only the current and previous data could be switched back and forth.

The current digits were also displayed when the DEK CLEAR key was pushed twice. This erased all digits selected but not entered and displayed the current digits which had been erased with the first DEK selection.

2.2 Legends and Switch Functions for Each MFK Page

The following pages show the multifunction switch legends for each system and note how each programmed switch functioned. The selection of a programmed switch either: (1) called up a new MFK page; (2) caused an asterisk (or green light) to be displayed for a different legend; or (3) in the case where the DEK was activated, caused an asterisk (or green light) to be displayed, until the ENTER key is pushed, for the multifunction switch legend which called up

the DEK. If an unprogrammed switch was selected, the message "OPTION N/A" was displayed for the appropriate switch on the CRT or projection switch type MFK.

The CRT format used in MFK configurations 1 and 4 is used as an example. As was mentioned earlier, in the MFK configurations 2 and 3, the current status (i.e., T/R&G for UHF) and pre-entry information was not displayed on the MFK itself. Rather, the information for the task being completed was displayed on MPD 2. Status information on the other systems was available on MPD 1.

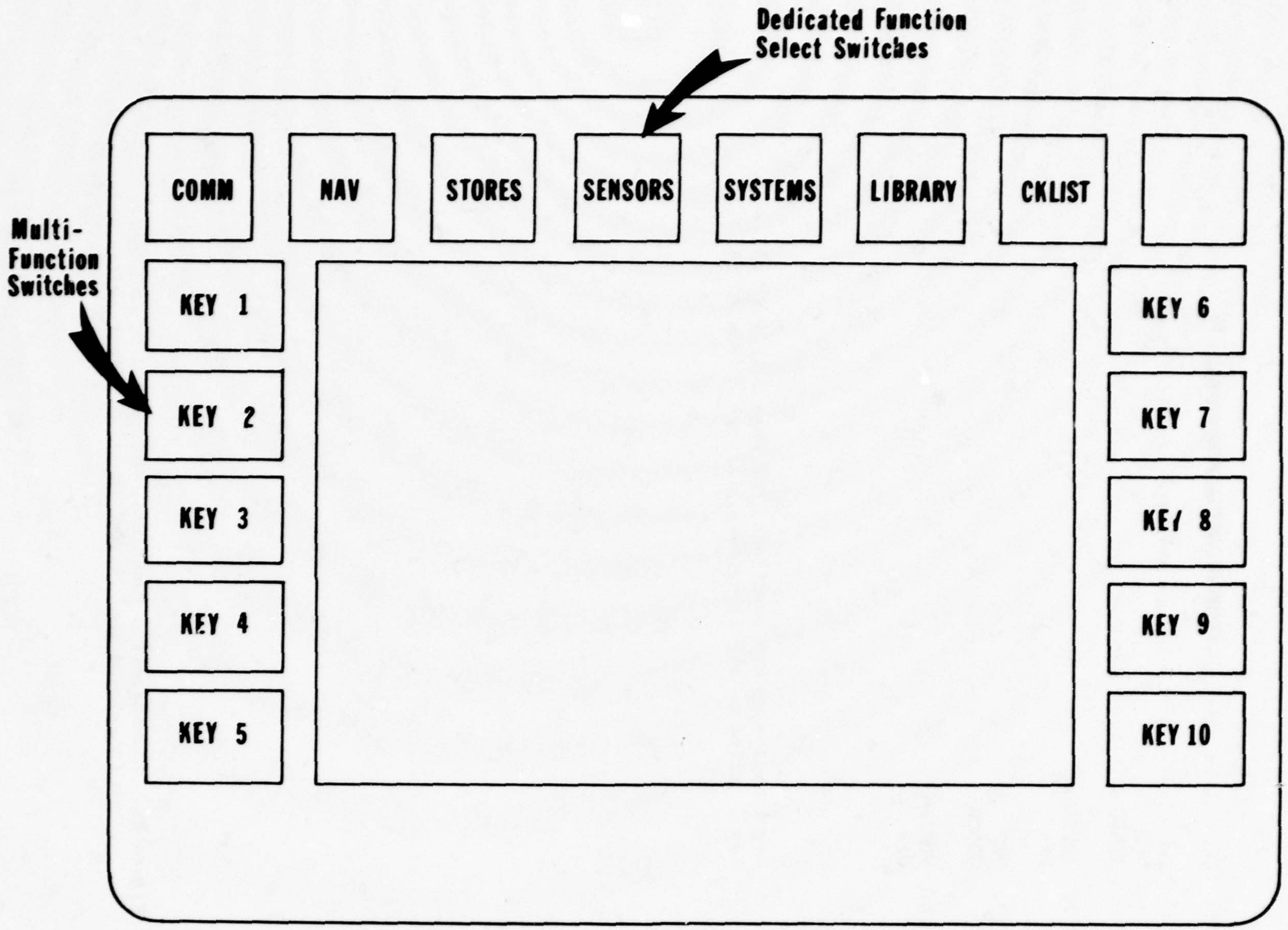


Figure E1. Drawing of MFK With Multifunction Switches Numbered.

COMMUNICATION FUNCTIONS

Page 1

1. UHF T/R&G	6.
2. ADF/AUX OFF	7.
3. IFF 35500	8.
4. VHF/FM OFF	9.
5.	10.

Key 1 Called up UHF functions, MFK page 2 (Figure E3).
Key 3 Called up IFF functions, MFK page 2 (Figure E4).

Figure E2. Communication Functions, MFK page 1
(Displayed when "COMM" function select switch selected.)

UHF FUNCTIONS

PAGE 2

1. UHF CHNG 340.3	UHF PREV 357.8	6. GUARD XMIT
2. *T/R+G		7. SQUELCH OUT
3. T/R		8. BEARING SAVE
4. ADF		9. BEARING ERASE
5. OFF		10. RETURN

Key 1 Activated the DEK for pilot input of the UHF frequency (4 digits, ENTER).

Key 10 Returned MFK to Communications, page 1 (Figure E2).

Figure E3. UHF Communication Functions, MFK page 2.
(Displayed when "UHF" multifunction switch selected).

IFF FUNCTIONS

PAGE 2

1. MODE/CODE	IFF 1-41 (2-1500) 3-5500	6. EMERG
2. STANDBY		7. RADN TEST
3. *NORMAL LOW		8. RADN MON
4. MODE IN/OUT		9. MODE 4
5. OFF		10. RETURN

Key 1 Activated DEK for pilot input of mode (3, ENTER) then code (4 digits, ENTER). The DEK deactivated when ENTER was selected after the code.

Key 2 Placed the system in warmup (standby condition). Asterisk was displayed by legend when system in standby.

Key 3 Applied power to the receiver/transmitter at either normal power or reduced power (alternate action switch). Asterisk was displayed by appropriate legends when system was in normal or low.

Key 4 Activated DEK for pilot input of mode number (1, 2, or 3) and ENTER.

Key 10 Returned MFK to Communications, page 1 (Figure E2).

Figure E4. IFF Communication Functions, MFK page 2.
(Displayed when "IFF" multifunction switch selected.)

NAVIGATION FUNCTIONS

PAGE 1

1. *IMS NORMAL	6. NAV UPDATE
2. DOPPLER ON	7. DATA ENTRY
3. ILS ON 109.7/254	8. STEER SELECT
4. TCN T/R 107X	9. MARK
5. NAV MODE	10. DISPLAY DATA

Key 4 Called up TACAN functions, page 2 (Figure E6).

Key 5 Called up Navigation modes, page 2 (Figure E8).

Key 7 Called up Data Entry modes, page 2 (Figure E7).

Figure E5. Navigation Functions, MFK page 1
(Displayed when "NAV" function select switch selected).

TACAN FUNCTIONS

PAGE 2

1. *T/R	TACAN PREV 104X	6. REC ONLY
2. TCN CHNG 107X		7. A/A T/R
3. TEST		8. A/A REC
4. CRS TO		9. CRS FROM
5. OFF		10. RETURN

Key 2 Activated DEK to accept TACAN channel change (3 digits and X).

Key 10 Returned MFK to navigation functions, page 1 (Figure E5).

Figure E6. TACAN Navigation Functions, MFK page 2.
(Displayed when TCN multifunction switch selected.)

DATA ENTRY FUNCTIONS

PAGE 2

1. WAYPOINT LOAD	DATA ENTRY	6. TARGET LOAD
2. CHANGE SEQUENCE		7. WIND SET
3. HOLDING FIX		8. ALT SET
4. HLDNG LFT		9. HLDNG RT
5. DELETE WAYPOINT		10. RETURN

Key 1 Activated DEK for pilot input of waypoint data (waypoint identifier - 2 digits, ENTER; latitude - 6 digits, alphanumeric, ENTER; longitude - 7 digits, alphanumeric, ENTER; ENTER).

Key 10 Returned MFK to Navigation functions, page 1 (Figure E5).

Figure E7. Data Entry Navigation Functions, MFK page 2. (Displayed when "DATA ENTRY" multifunction switch selected.)

NAV MODE FUNCTIONS

PAGE 2

1. *NORMAL	NAV MODE	6. DEAD RCKN
2. DOPPLER INERTIAL		7. WIND SET
3. INERTIAL		8. MAG SLAVE
4. DOPPLER		9. GRID
5. TACAN		10. RETURN

Key 5 Changed Navigation mode to TACAN. Flight director steering (lateral axis) would now be TACAN derived.

Key 10 Returned MFK to Navigation functions, page 1 (Figure E5).

Figure E8. Navigation Mode Functions, MFK page 2. (Displayed when "NAV MODE" multifunction switch selected.)

STORES FUNCTIONS

PAGE 1

1. 18 MK 82	6. LIST BY STA
2.	7. DISPLAY OPTION
3.	8.
4.	9.
5.	10. DISPLAY JETT PROG

Key 1 Initiated creation of a different delivery option for the specific weapon type by bringing up weapon dependent page 2.

Figure E9. Stores Functions, MFK page 1
(Displayed when "STORES" function select switch selected.)

MK 82 FUNCTIONS

PAGE 2

1.	QUANTITY <u>18 MK 82</u>	6.	SEL STNS ALL
2.	SINGLES	7.	
3.	INTERVAL	8.	SAVE
4.	FUZE NOSE	9.	ACTIVATE
5.	FUZE TAIL	10.	RETURN

Key 1 Activated DEK for pilot input of quantity (2 digits, ENTER).

Key 2 Activation caused the release mode to be changed in sequence (SINGLES, PAIRS, SALVO).

Key 3 Activated DEK for pilot input of interval (feet) between impact points on the ground (2 digits, ENTER).

Key 4 Selected NOSE FUZE.

Key 5 Selected TAIL FUZE.

Key 8 Activated DEK for pilot input of option identifier number (1 digit, ENTER).

Key 10 Returned MFK to STORES functions, MFK page 1 (Figure E9).

Figure E10. MK 82 Functions, MFK page 2.
(Displayed when "MK 82" multifunction switch selected.)

NAV BOMB FLIGHT MODE

PAGE 1

1.	UHF CHNG 387.4	6.	WEAPON OPTION 1
2.	BOMB TGT	7.	WEAPON OPTION 2
3.	ALT HOLD	8.	WEAPON OPTION 3
4.	AUTO HDG	9.	WEAPON OPTION 4
5.	ALT SET 30.12	10.	CRS SET

Key 1 — Activated DEK for pilot input of UHF frequency (4 digits, ENTER).

Keys 6, 7, 8, & 9 — Permitted selection of programmed weapon options 1, 2, 3 and 4, respectively, which were displayed on MPD 2. After selection of one of the four options, the Tailored Mode Page 2 for the selected weapon type was displayed on the MFK. Figure E12 is an example of such a page. Upon return (selection of RETURN switch) to page 1 of the selected Tailored Mode, the parameters for the selected option were displayed on lines 1 through 6 of the MFK center column; e.g.,

16 MK 82
PR
ALL
90 FT
NT
ACTIVATE
M/A

Figure E11. NAV BOMB Flight Mode Functions, MFK page 1. (Displayed when NAV BOMB flight mode switch selected.)

SELECTED WEAPON OPTION PAGE

PAGE 2

1. QUANTITY	18 MK 82	6.	SEL STNS ALL
2. PAIRS	16 MK 82 PR	7.	
3. INTERVAL	90 FT NT	8.	
4. *FUZE NOSE	ACTIVATE M/A	9.	
5. *FUZE TAIL		10.	RETURN

Key 10 Returned to NAV BOMB flight mode functions, MFK page 1 (Figure E11).

Figure E12. Selected Weapon Option Page, MFK page 2.

APPENDIX F

PILOT QUESTIONNAIRES

Immediately after each flight the pilot was given a two page questionnaire concerned with the design of the activated MFK configuration and how progression through the logic implemented on the MFK configuration compared with the operation of the standard control head for each function. The pilots' responses to these questions concerning the four MFK configurations appear first in the appendix. Next, are the pilots' responses to the final debriefing questionnaire. This questionnaire was administered following the completion of all data flights and was designed to elicit subjective evaluation of the MFK configurations, keyboard logic, display formats, and simulation quality. (Editorial comments are contained within brackets.)

KEYBOARD IMPLEMENTATION STUDY QUESTIONNAIRE

The purpose of this questionnaire is to obtain your opinion on the acceptability and useability of the four different Multifunction Keyboard (MFK) configurations. In addition, we are also assessing the difference between the MFKs and the Standard Control Heads in the A-7. The value of this questionnaire depends on your personal analysis. This analysis will aid in the improvement of effective MFK designs. If you desire to explain your answer feel free to comment in the space provided and please be as specific as possible.

I. PERSONAL DATA

Name ____

Total Flying Time ____________________ Total Jet ____________

Current Aircraft ____________________ Hours ____________

Civilian Job ____

Mean Total Flying Time: 2563 Hours
Mean Total Jet Time: 2412 Hours
Current Aircraft: A-7
Mean Hours in Current Aircraft: 435 Hours
Civilian Job: 10 Pilots: None
1 Pilot: Real Estate Agent
1 Pilot: Physicist
1 Pilot: Student
1 Pilot: Carpenter
1 Pilot: Engineer
1 Pilot: Psychotherapist

1. For each function (i.e., UHF, IFF, TACAN, NAV-waypoint, STORES) compare the standard control head with the logic implemented on the MFK configuration. Check (✓) the appropriate box.

	Std. Control Head Much Better Than MFK	Std. Control Head Slightly Better Than MFK	Equal	MFK Slightly Better Than Std.	MFK Much Better Than Std.
H1. (CRT version on the front left panel)					
UHF		1	2	7	6
IFF	3	3	1	7	2
TACAN	2	3	3	6	2
NAV-wpt.		2	4	6	4
STORES	2	1	6	3	4

Comments:

- From my eye position, legend on CRT is not aligned very well with keyboard. IFF and TACAN - Too many steps. Status of systems would be more convenient on left hand CRT.

- The display was not aligned with the buttons. Things seemed easier because I've begun to learn the location of buttons and the order of events in the decision tree.

- CRT needs to be located as high as possible under a glare shield to preclude the pilot from having to bury his head in the cockpit. Current size of print

is too small for even 20/20 vision. Lefthand keyboard is awkward for me (righthanded). I can fly better lefthanded and keyboard right for some reason.

- Changing NAV modes still requires too many steps. UHF changes are becoming easier with practice. Parallax still a problem.

- I believe that with a little more familiarization I would prefer the MFK much better in all modes. There seems to be more steps to perform, plus I have to look at both sides of the cockpit to confirm information entered.

- Much easier to set manual frequency with a keyboard than it is with our rotary selectors, especially for UHF and not so much easier for TACAN and IFF. It will be even better with preset channel capabilities. I like the option method for stores because it allows the pilot to see the configuration he can select and is set up for.

- UHF - MFK1 is equal to A-7 UHF panel but remember that the A-7 panel is very poor. NAV Wpt. - MFK1 is better due to its position. It is easier to get at and read.

- UHF - Good because of two channel capacity. Seems easy to change. IFF - Good readout of modes. Almost as easy to change as standard IFF/SIF. TACAN - With standard equipment, pilot is able to quickly select a new radial with tail of the CDI and does not have to make any mathematical subtractions (mine were gross). Rough bearing can be set quickly (std) and then refined when conditions permit. STORES - Four weapons options is a good idea. Appears to

be too time consuming a task to be undertaken in the target area when a rapid change is necessary.

- UHF - Would like to see UHF CHNG displayed in cruise mode. IFF - Too many steps. STORES - Too many steps to change a load while at target. Other than that it is OK. This is best configuration from standpoint of having all information in same place.

- This panel location much better.

- The locations of H1 and H2 were excellent, but H2 was much easier because of the lighted switches. It is easier to touch a button that is lit up with what you want to hit.

- Lighting with CRT on front left panel is much better. Able to enter data and see CRT display with less effort because of closeness of the two. "A big plus": Pilot can reach panel with throttle arm (left hand) and no head or body movement forward. Tailored mode UHF change while in NAV BOMB function is superior.

2. Rate each of the following aspects of the MFK you used in this flight, H1. Check (√) the appropriate box.

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum (SH)
a. Location of Panel		1	4	8	3
b. Button Arrangement		1	4	9	2
c. Size of Switch		3	6	5	2
d. Readability		2	5	7	2
e. Legend Arrangement	1	1	7	4	3
f. Pre-entry Readout		1	9	2	4
g. Legibility	1		7	5	3

Comments/Improvements:

- Use of left hand for switches is good. Allows right hand freedom for flying. Use of double entry for waypoint load may be a problem and forgotten. Use of a different color entry button that lights when time to enter may be helpful.

- CRT print is too small and mounted too low from outside references.

- Legends not aligned with buttons.

- Switches beside CRT may be a little small. Parallax error as noted.

- Less head and eye movement, slower cross check required with CRT and VSD* close together. This is a definite plus. Moving panel to left console close to throttle still seems better.

- Position of MFK1 is very good. Left side of instrument panel is probably best place to have a control panel. Difficulty is from confusion caused by multiple operations required to change some modes. Display on screen is too small and hard to read. Letters and numbers should be larger. Ø is not required to indicate zero. No differentation is required between zero and the letter O. Ø looks like 8.

- Legibility not quite as good as H2 because the information wasn't on the dial but instead on the CRT which was slightly more difficult to see.

- The five function switches on each side of the CRT could be slightly larger. They weren't exactly aligned with the corresponding readouts. I was counting down to locate the proper buttons. Unfamiliarity is still a problem, but possibly a double scale readout of some sort during the "typing" step would draw more attention to that process.

*During testing and questionnaire adminstration, the VSF and HSF were referred to as VSD - Vertical Situation Display and HSD - Horizontal Situation Display, respectively. After the study, it was decided to employ the word "format" since the information could be presented on a number of displays.

- Side buttons on CRT fail to take into account parallax error, i.e., do not align arrows and legends very well. DEK is hard to reach.

- Location of panel improves cross check of VSD significantly.

- Keyboard is much harder to reach over the throttle than it was on the right console. But the buttons on the CRT should be as close to the keyboard as possible. I think the buttons and keyboard should be located together on the left console as they are on the right side.

- TACAN Channel Change - Why not rearrange buttons so that same button is used to designate TACAN and TACAN channel change?

- Good location. After a few minutes operating this, it was very easy. However, first few times had problems reading keyboard-ran into throttle.

- Location of CRT on left side very awkward and size of side buttons were rather small and due to this more time is spent making sure the wrong button or double buttons weren't pushed. I personally like this particular CRT better even though it was more difficult during the mission; everything was in one location around the CRT.

3. For each function (i.e., UHF, IFF TACAN, NAV-waypoint, STORES) compare the standard control head with the logic implemented on the MFK configuration. Check (✓) the appropriate box.

H2. (Projection switch version of an MFK on the front panel)	Std. Control Head Much Better Than MFK	Std. Control Head Slightly Better Than MFK	Equal	MFK Slightly Better Than Std.	MFK Much Better Than Std.
UHF		3	2	4	7
IFF	1	5		6	4
TACAN	1	2	6	4	3
NAV-wpt.		3	5	5	3
STORES	1	4	2	4	5

Comments:

- Most of my problems were due to unfamiliarity with the decision tree. I think I should become proficient with the use of the decision tree before I made a comparison between the systems. To help with the decision tree there may be cases where you could display a prompting statement with a question mark, e.g., for IFF change a "Mode ?" could be displayed when time for a mode entry and then "Code ?" when time for code entry.

- IFF difficult and time wasting. UHF in NAV BOMB mode better than control board.

- This one the easiest of all four systems to run. Like the idea of buttons turning green when function selected. Having pre-entry display on opposite side no problem - don't use it for TACAN, radio, IFF changes - only for weapon and waypoint and that'll generally be on the ground.

- UHF - Would like to see UHF CHNG displayed in cruise mode. IFF - Too many steps. STORES - Too many steps to change a load while at target. Other than that it is OK. Panel positioning seems to make more sense except I have more trouble hitting buttons with my left hand. I think keyboard should be on console or somehow be less vertical.

- Much easier to set manual frequencies with a keyboard than it is with our rotary selectors. Especially for UHF and not so much easier for TACAN and IFF. It will be even better with preset channel capabilities. I like the option method for STORES because it allows the pilot to see the configuration he can select and is set up for.

- UHF - MFK2 better but A7 panel is not very good. TACAN - MFK2 better but A-7 panel is not very good. IFF - MFK2 better but A-7 panel is not very good. STORES - STORES functions on MFK2 are still confusing and slow to accomplish. Suggest Master Arm lights next to Master Arm switch. Red for safe, green for armed and ready.

- In all modes some difficulty was experienced in using left side of cockpit for data entry and right side of cockpit for data display.

- Position of MFK better on left side but would prefer it on left console to rear of throttle. This MFK allows pilot to keep right hand on control stick. Would prefer panel on left side beside VSD.

- TACAN - Too many steps. Have to mentally compute inbound course without aid of compass rose. Cockpit lightly poor, different to read Form 70.

4. Rate each of the following aspects of the MFK you used in this flight, H2. Check (✓) the appropriate box.

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum (SH)
a. Location of Panel		1	5	7	3
b. Button Arrangement			4	8	4
c. Size of Switch			4	5	7
d. Readability			5	4	7
e. Legend Arrangement		1	7	6	2
f. Pre-entry Readout	1	2	7	3	3
g. Legibility		1	2	9	4

Comments/Improvements:

- Pre-entry readout could be on same side of panel.

- Had to move knee to see panel. MFK should be nearer top of instrument panel.

- "Master Arm" prior to actual switch movement to on. "Ready" after Master Arm selected.

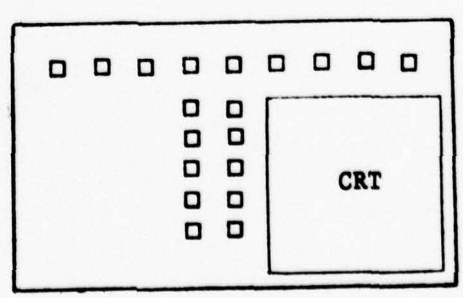
- Readout being on right side of the cockpit with buttons on the left console caused some difficulty in verifying data entry.

- If MFK were situated close to left hand, which normally is on throttle, it would cause less movement in cockpit which (movement) is a degradation of aircraft control and instrument concentration. Control buttons seemed to be a shade bigger on the MFK compared to right console MFK.

- CRT numbers too small.

- Panel location is very good but could be further improved by implementation of suggestion (below). Projection switches are good and easy to read. CRT is hard to read because print is too small. Switch action is not the best. Switches sometimes must be pressed 2 or 3 times. Legibility - Projection switch was very good, CRT was unacceptable. Readability - Projection switches very good, CRT unacceptable. DEK and MFK-2 control panel could be arranged so that they could be pulled out of the instrument panel in a drawer arrangement, so that they would be positioned just above pilot's left knee. This would provide optimum position for operating and reading, especially for maneuvering flight or under G load.

Suggestion for Improved MFK-2



- Only possible improvement of panel location would be to locate slightly higher all DEKs etc to keep head from being buried in cockpit all the time.

- Panel Locátion - The higher the better, the less head movement to look outside.

- Large buttons bests.

- The legend "Activate M/A" tended to remind me of "Weapon Option N/A" so I ignored it often. Suggest spelling out "Master Arm" and making it flash. Mode In/Out status should be displayed on MPD. [It is displayed on MPD].

- Best location.

5. For each function (i.e., UHF, IFF, TACAN, NAV-waypoint, STORES) compare the standard control head with the logic implemented on the MFK configuration. Check (✓) the appropriate box.

	Std. Control Head Much Better Than MFK	Std. Control Head Slightly Better Than MFK	Equal	MFK Slightly Better Than Std.	MFK Much Better Than Std.
H3. (Projection switch version of an MFK on the right console)					
UHF	2	3	1	5	5
IFF	5	2	3	2	4
TACAN	3	3	6	1	3
NAV-wpt.	1	2	8	2	3
STORES	1	3	6	1	5

Comments:

- UHF - Would like to see UHF CHNG displayed in cruise mode. IFF - Too many steps. STORES - Too many steps to <u>change</u> a load while at target. Other than that it is OK. I like having projection on buttons. Changing from INS to TACAN NAV Modes is too difficult. Would be nice to be able to monitor both simultaneously.

- Keyboard on right wasn't as advantageous as I had thought. Initially I had trouble flying left handed and typing with my right as in the A7. Ultimately I guess maybe left hand keyboard location would be better. Especially like UHF and UHF change appearing under the same button.

- Much easier to set manual frequencies with a keyboard than it is with our rotary selectors. Especially for UHF and not so much easier for TACAN and IFF. It will be even better with preset channel capabilities. I like the option method for STORES because it allows the pilot to see the configuration he can select and is set up for. Waypoint does not need an enter for both the North and West coordinates.

- UHF - Major reason I rated A-7 UHF panel better is the simplicity of the channelization knob. Channels can be changed by feel in the A-7. This is difficult with MFK-3. Changing frequencies with MFK-3 is about the same as in A-7, however, A-7 UHF panel is notoriously poor. IFF - Making IFF changes with MFK-3 was difficult and confusing. A-7 panel is easier although it is far from optimum. TACAN - Standard control head is simpler and easier to use. NAV Waypoint - MFK-3 almost as good as A-7 panel, but MFK-3 is more confusing due to the many options and modes displayed. STORES - A-7 panel would be hard to beat.

- NAV Waypoint - Still too many steps. Using right hand very comfortable, but probably impractical to fly with left hand. I like the remote CRT readout of to-be-entered data, so you don't have to search through much data to find if your info is correctly typed in.

- These [functions] would all be easier if I could fly with the right hand. I much prefer the function switches to be displayed on the instrument panel rather than the side console.

- Too many steps and "ENTERS" needed in the NAV Waypoint changes. Same problem with IFF.

- Master Arm switch is a toggle switch (it should be) and I had trouble remembering to look for it - I was concentrating on keyboard. I confused M/A with N/A and didn't realize the display was prompting me to activate the Master Arm. Suggest a flashing display "Master Arm".

- IFF and TACAN - Too many steps. STORES - Less chance for switchology errors. Using right hand does not seem as difficult, probably because switches are placarded.

- Entering/changing TACAN, Radio, IFF is much faster in standard configuration and error correction much easier and faster in standard.

- Much easier when legend appears on buttons. UHF change much easier in NAV Bomb mode.

- If MFK were located on left console it would be easier to control aircraft (no switching hands). Also, prefer readout screen on left front - perhaps basic instruments to right side and screen to vacated spot.

6. Rate each of the following aspects of the MFK you used in this flight, H3. Check (✓) the appropriate box.

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum (SH)
a. Location of Panel	3	4	6	2	1
b. Button Arrangement			9	4	3
c. Size of Switch			4	8	4
d. Readability		1	8	2	5
e. Legend Arrangement			10	4	2
f. Pre-entry Readout	1	2	5	3	5
g. Legibility		2	6	4	4

Comments/Improvements:

- Prefer not to have "head buried in cockpit".

- I don't like to fly with my left hand while punching buttons. Tougher to read buttons because of position on lower panel.

- I really like the panel on the right. Right hand on the keyboard, kneeboard on right leg, displays on the right side - it makes for an easy crosscheck. However, it requires moving the head down and to the right. This would present no problem in good weather where peripheral vision can be used for

attitude reference. It would present no problem if the auto pilot were working OK. However, it would present a problem when hand flying in weather or in close formation.

- Location - Terrible to have to fly with left hand. Pre-entry Readout - This readout is very useful and must be immediately visible - but in this configuration, the readout doesn't stand out when activated.

- CRT numbers still too small.

- Move MFK and panel to left side. HSD is outstanding.

- Make TACAN change and IFF change like UHF.

- Maybe CRTs could be located on both sides of cockpit as you could look out either side and catch them with the least head/eye movement. Print must still be larger. Maybe too much data anyway. HSD - Stick blocked information at the bottom. Groundspeed (most important for low level navigation), DME to go and time to go should be moved to the upper right corner of HSD. Time and distance to target especially important also if a TOT has to be met and you are late; you would then cut off legs and proceed direct to target. Need heading available at all times. Example:

T8 214 NM
38.6 Min
078

THINK DUMB

VSD - Too small both for minor pitch/bank corrections and for at a glance interpretation. Where's the yaw indicator? Heading scale needs to be expanded for precise heading control.

- Still hard to be "typing" in one spot and having to move eyeballs to "read" in another spot.

- Some difficulty in maintaining aircraft control when all data entry requires use of right hand.

- Provide UHF change in cruise mode.

7. For each function (i.e., UHF, IFF, TACAN, NAV-waypoint, STORES) compare the standard control head with the logic implemented on the MFK configuration. Check (✓) the appropriate box.

	Std. Control Head Much Better Than MFK	Std. Control Head Slightly Better Than MFK	Equal	MFK Slightly Better Than Std.	MFK Much Better Than Std.
H4. (MFK on the right console with the corresponding legends displayed on a front panel CRT)					
UHF	4	3	5	1	3
IFF	7	3	3	2	1
TACAN	3	6	5	1	1
NAV-wpt.	1	6	3	3	3
STORES	3	6	2	2	3

Comments:

- This console is tough to judge because of flying left handed. All tasks were hard due to this.

- This is the worst arrangement possible. Hard to locate keyboard/function buttons. Hard and time consuming to continually crosscheck instrument panel against console - very easy to make a mistake with this system. Since error correction is one of the more time consuming tasks, this method is unacceptable.

- Some difficulty in determing the correct button on the console as it applied to the screen. Found myself counting the position of the information desired and then counting to determine which button to press. UHF frequency change is the most frequent change in flight. I found myself flying the simulator with my left hand more often than desired.

- These buttons [multifunction switches] are very difficult to differentiate due to poor light and no touch difference.

- UHF - Would like to see UHF CHNG displayed in cruise mode. IFF - Too many steps. STORES - Too many steps to change a load while at target. Other than that it is OK. General - Buttons should also be labeled if possible, particularly for night flying.

- Tailored UHF mode (NAV. delivery with 10 most important options displayed) is outstanding, especially when time is critical and things are happening fast. Lack of lights on MFK causes pilot to take longer to respond, i.e., tends to cause a speeded up crosscheck between TV screen and console panel. Setting throttle and locking throttle friction plus using both hands on control stick makes use of right console MFK easier.

- Need three-way rotary for IFF; OFF/STBY/ON. Too many switch selections needed. Too many steps required for NAV mode change. Parallax creates some problems with switch selections. Having to correlate CRT readout and switch selections requires one more mental step. "If God had meant for pilots to fly left handed, He would have given them two left hands."

- Its just more difficult to coordinate the screen with the buttons, i.e., counting down numbers on the screen - then counting down buttons. Became "more tolerable" with practice. Maybe put numbers on the buttons and number items on the screen for easier coordination.

- This one causes aircraft control to suffer. You have to look up at the TV tube then back to the panel and count the one you want to select.

- No console lights make projection switches very hard to see, therefore, difficult to operate. Main difficulty is correlating position of functions on CRT with the switch panel on the right console. Should have dimmer rheostat for CRT display. All CRT symbology is too small and difficult to read.

- Too much time wasted looking first to CRT and then counting Braille on keyboard.

8. Rate each of the following aspects of the MFK you used in this flight, H4. Check (✓) the appropriate box.

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum (SH)
a. Location of Panel	4	5	4	2	1
b. Button Arrangement		2	10	3	1
c. Size of Switch			6	6	4
d. Readability	4	3	3	4	2
e. Legend Arrangement	1	3	6	6	
f. Pre-entry Readout		3	5	6	2
g. Legibility	1	1	8	3	3

Comments/Improvements:

- I liked the large button size. They were easier to use with gloves on.

- The lower scores [location of panel] are due to the back and forth movement of your eyes.

- Function switches were hard to see since they weren't illuminated in anyway. Logical switching steps should probably be programmed with flashing CRT display (such as "Bomb Arming" and "Return" during a Weapons Mode).

- Bank angles [bank scale and pointer] fuzzy on VSD. Blue showing under armpits of aircraft symbol is good indication of slight bank.

- Dark in right console area, made selections more difficult. It's possible that numbers on switches with corresponding numbers on CRT would be easier.

- Panel location is bad. Must look down to right to see panel. Panel and CRT are not together. Readability and legibility are poor due to small characters on CRT.

- Lack of lights in MFK panel is a minus. In formation it would be dangerous, in that wingmen would spend too much time looking back and forth from screen to MFK panel to check on which unlit button to press for a particular response. Chances are he would be very slow for any input, especially in weather when aircraft control on a wing is difficult and he is glued on the leader. In VFR conditions and spread formation it would not be a factor.

- Again flying with my left hand is a major problem. Seems difficult to me to punch the blank buttons and coordinate with the display on upper panel. Too much time spent looking back and forth.

- Change feel of the buttons to make it easy to use them without looking at them.

- When entering data, the readout is difficult to scan due to small size.

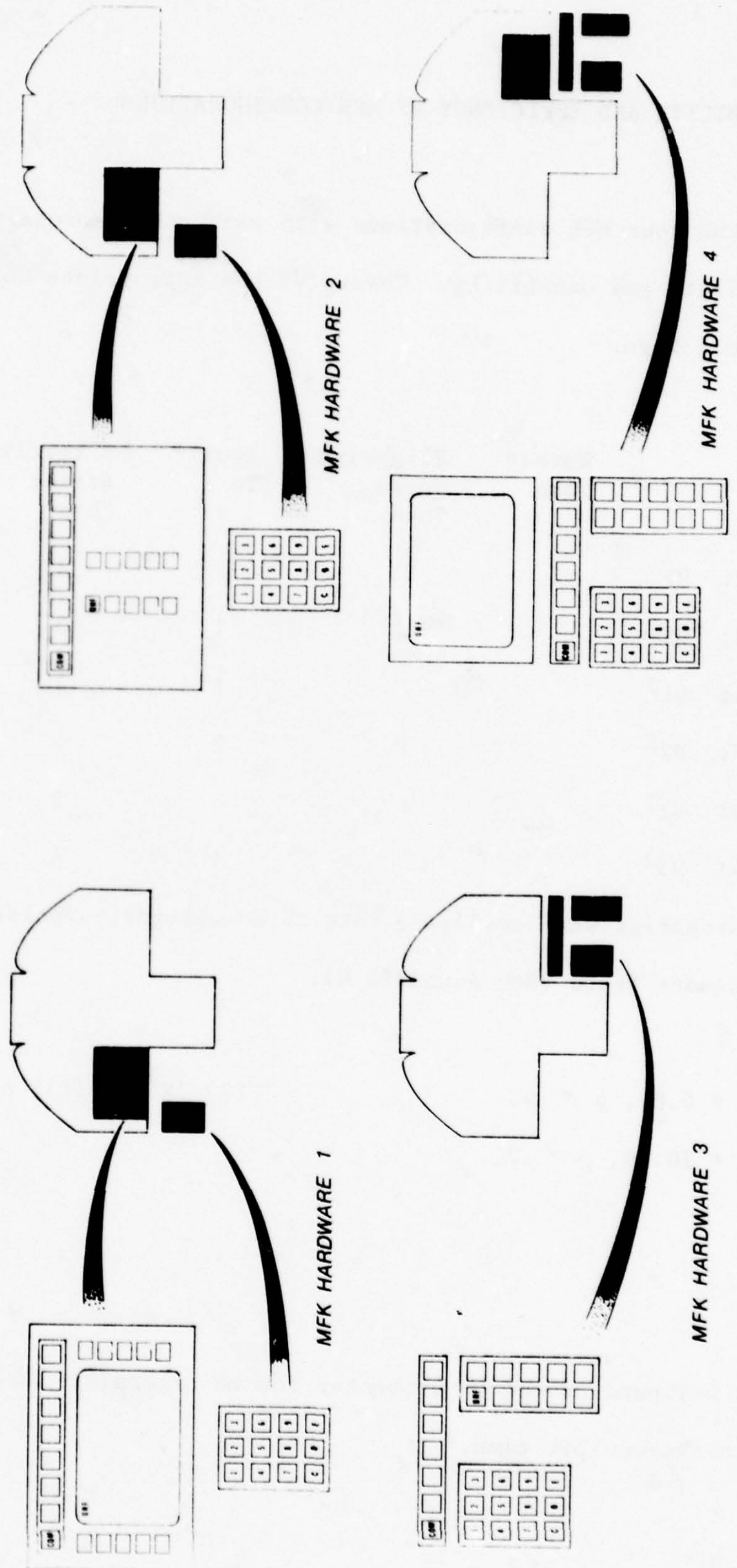
- Panel location not unacceptable unless it is for primary use.

- Too much attention required to interpret correct switches, too many steps. Location is undesirable due to requirement to change hands on control stick.

- D., E., F. - Main problem with these is unfamiliarity. Had to read a lot - search for an item among a lot of other information projected on screen. A lot of head movement back and forward from the projection switches to the CRT. Had to count down from the CRT screen to find functions.

- Might consider putting 1 in lower left of keyboard as on adding machine. I like working with my right hand but this assumes singleship flight and use of autopilot. All of this might be impossible to do while flying close formation.

- Use of right hand on number keyboard was easy but the displacement of the function buttons from the display was confusing. Display panel's location was OK.


MFK HARDWARE 1
MFK HARDWARE 2
MFK HARDWARE 3
MFK HARDWARE 4

II. ACCEPTABILITY AND EFFICIENCY OF MFK CONFIGURATIONS

1. Compare the four MFK configurations with each other, assessing their overall acceptability and useability. Check (✓) the appropriate box. See Figure on Previous Page.

	Worse* Than	Slightly* Worse Than	Equal* To	Slightly* Better Than	Better* Than	
a. H1 vs H2: H1	3	3	3	2	5	H2
b. H1 vs H3: H1[1]		4	1	3	8	H3
c. H1 vs H4: H1[2]			1	3	12	H4
d. H2 vs H3: H2[3]		3	2	4	7	H3
e. H2 vs H4: H2[2]		1		3	12	H4
f. H3 vs H4: H3[2]			1	6	9	H4

*The five categories were collapsed into three categories prior to the conduct of the Chi-square tests (See Appendix G).

(1) $X^2 = 9.88$, $p < .01$

(2) $X^2 = 26.38$, $p < .01$

(3) $X^2 = 9.13$, $p < .05$

Comments:

- Left hand keyboard proved to be better for me afterall. H4 requires too much head-in-the-cockpit time.

- Ranking:	1-2 Best	[This pilot rated H2 as the best configuration, followed by H1, H3 and H4, in order.]
	2-1	
	3-3	
	4-4	

H3 and H4 were last because of realities of trying to accomplish tasks flying with left hand. Next most important aspect was projection switches are <u>far</u> superior to CRT readout. Next most important aspect is comfort and dexterity of using right or left hand.

- H1 display is best except keyboard is harder to use due to being at arms length. Under any G's, turbulence, pilot nervousness, etc, these keys are harder to hit accurately.

- Switching in H1 and H4 much more difficult than H2 and H3.

- H1 was best for me.

- H3 buttons were better than H4, but H4 display on panel was a plus over H3.

- MFK 1 hardware was the best but location was not optimum.

- H2 by far the easiest to deal with. H4 by far the worst.

- H4 - Trouble with buttons and display match up. H3 - Too much left hand flying. H2 - Information on two sides of cockpit.

- H1 could be better by enlarging side buttons and aligning them better with CRT [legends]. H1 worse than H2 because of parallax and switch size.

- H3 is ideal except located on wrong side.

- H4 is by far the worst MFK configuration.

2. Circle the MFK configuration(s) you would like to see incorporated into future cockpits?

H1	7 pilots circled H1
H2	7 pilots circled H2
H3	4 pilots circled H3
H4	1 pilot circled H4
None	2 pilots circled None

Why?

- H2 with some modification. Need a printout next to keyboard to read what is typed as it is typed.

- H1 and H2 because of ease of crosscheck with VSD. It was easy to interpret. H1 is preferred but H2 is acceptable.

- H1 is easy to operate and a good information display.

- H3 will work in any airplane which is not going to fly formation and for the most part is very useful. Some parts of the program, e.g. changing NAV Modes have so many steps that it is irritating but this can be worked out. The overall is good.

- H2 and H3 are logical and relatively errorless.

- H1 - OK with better CRT/Button alignment. H2 - Very easy to use. H3 and H4 - Awkward, don't like to fly with left hand.

- H4 because the display is in front and you can operate buttons by feel. Best would be buttons on left, displays in front but the throttle causes a conflict here.

- H1 because everything is right around the CRT and ease of viewing.

- H2 and H3 because these two light up the things you want to press and for us fighter pilots that is the easiest.

- H2 - CRT is too small and hard to quickly focus on. I really prefer light/button/color presentation and color gives you an added dimension to work with. Also it's simple.

- H2 - Computer entry is easier than current A-7D cockpit design. STORES Options - The only way to go. UHF changes easier (also TACAN and IFF if the switches are set up as previously suggested).

- H1 because it is on the left and the panel buttons [multifunction switches] and keyboard are together. H3 because the keyboard and buttons are close together and the buttons were easiest to read when they light up instead of reading the screen.

- None are ready to be incorporated into cockpits yet, however, H1 and H2 show great promise. I believe these configurations will eventually be suitable for use in fighter cockpits, but they need a lot of work.

- None. H1 is closest to being desirable. It would be improved with push buttons placarded, and some functions remechanized (mostly software). Should be higher on left side of panel.

- H1. My initial reaction is to answer none because all of the standard control heads in the A7 are familiar to me and easier to work at this time. H1 seems to have a lot of possibilities for future use and functions in the cockpit. It is by far and away the best of the four MFKs; I like using my left hand on the keyboard and location of the keyboard to CRT and other buttons. Having all of the components on the upper panel keep eye and head movements to a minimum and is also easy to reach by hand.

3. Which of the four MFKs is the best?

H1	H2	H3	H4
7	7	2	1

[One subject selected H1 and H2.]

Why?

- H1 - Everything is right around the CRT and ease of viewing.

- H3 - Keyboard is on right. Otherwise H1 is best as far as the display goes. It would be better if keyboard could be moved closer and possibly less vertical.

- H2 - Location is the best and you touch what is lit.

- H1 or H2 - They are in optimum location in panel and are reasonably easy to read.

- H2 - Computer entry is easier than current A-7D cockpit design. Stores Option - The only way to go. UHF changes easier (also, TACAN and IFF if the switches are set up as previously suggested).

- H2 - Left side installation plus large buttons.

- H1 - Data being entered is nearest the display.

- H3 - Keyboard was most operable. Buttons were easy to recognize quickly.

- H2 - CRT is too small and hard to quickly focus on. I really prefer light/ button/color presentation and color gives you an added dimension to work with. Also is simple.

- H1 - Easier for me to read.

- H1 - Seems to have a lot of possibilities for future use and functions in the cockpit. It is by far and away the best of the four MFKs. I like using my left hand on the keyboard and location of keyboard to CRT and other buttons. Having all the components on upper panel keeps head and eye movements to a minimum and is also easy to reach by hand.

- H4 - Once I learned the feel of the buttons, I didn't have to look at them. I liked the position on the right - it didn't require extending the arm to reach them.

- H1 - Use of left hand for data entry display and buttons together.

- H1 - Lighting is better. Location close to VSD is good. Less head and body movement, or less effort required to operate CRT [H1].

- H2 - Easiest to use - less chance of error.

- H2 - Allowed easier flying while punching and easier to select correct buttons.

4. Considering these functions (i.e., UHF, IFF, TACAN, NAV-waypoint, STORES), compare the standard control head with the logic implemented on the best MFK. Check (✓) the appropriate box.

Standard Much Better Than MFK	Standard Slightly Better Than MFK	Equal	MFK Slightly Better Than Standard	MFK Much Better Than Standard
1	3	1	6	5

Comments:

- With more practice and different switchology this could have been <u>much better</u>.

- I think I would like it [H4] much better after I became proficient with it.

- I am so familiar with standard cockpit switches that I can operate them without reading them and almost without looking. This system requires thinking, which most fighter pilots don't do too well.

- Some standard switchology lends itself to working without looking, i.e., known channel on radio - you can move so many clicks in one direction to get another known channel.

- Interpreting status and making changes seems more complex, less straightforward. Possibly more experience with MFK would modify opinion.

- STORES is much better, Waypoint is OK, IFF, UHF and TACAN very good.

- H2 would be slightly better if IFF were left out and numbers on CRT were better.

- System readout on right side of cockpit is super.

- COMM good when UHF CHNG button readily available.

- Standard is more familiar to me and easier to use at this time.

- I would probably like H1 better if I had more experience with it. Having all the switches in one place in front of you instead of all around is quite an advantage. IFF is the exception. I prefer the standard IFF.

5. Rate the configurations listed below on the criterion of operation time for each of the following tasks: UHF, IFF, TACAN, NAV-waypoint, and STORES. Use the rating scale:

1 = Very Slow, 2 = Slow, 3 = Average, 4 = Fast, 5 = Very Fast

	UHF	IFF	TACAN	NAV-wpt.	STORES
a. Std. Control Heads	2.69*	2.88	3.56	3.06	3.5
b. H1	3.25	2.56	2.88	2.94	2.94
c. H2	3.06	2.63	2.88	2.88	2.88
d. H3	3.06	2.5	2.63	2.69	2.69
e. H4	2.63	2.38	2.56	2.56	2.63

*Each entry represents a mean of sixteen responses.

Comments:

- STORES could be rated much higher because once option is loaded, the time to select it is excellent. This task is very important in that it normally comes during a very demanding period of flight. UHF change was much better during NAV Bomb phase and would be a "five". DEK is too far away in H1 and H3 to provide good accessibility except in straight and level flight.

- Would have put IFF in the NAV function. Each time completed IFF task had to pause and think which function select switch to push (COMM or NAV).

- Since TACAN CHNG is a frequently executed function, it perhaps should be on key 1.

- H4 seemed slower because of the extra mental step of correlating switches with CRT.

- The reason MFKs are slower is the number of steps in most cases. This would improve with practice I'm sure, but it would still take a long time to change a weapon option while in the target area or to change over to TACAN if the IMS dumps.

- Keyboard is <u>much</u> <u>much</u> better than rotating selectors through the frequencies on UHF and IFF. Introduction of coordinates could be much improved with little work in the way of changing some of the entry steps.

- With more use of this system, I can see how one could become extremely fast. From the beginning of the day to the end of the day, my proficiency had improved already.

6. Rate the configurations listed below on the criterion of number of errors for each of the following tasks: UHF, IFF, TACAN, NAV-wpt., STORES. Use the rating scale:

1 = Too Many Errors, 2 = More Than Average, 3 = Average, 4 = Very Few, 5 = Can Use Without Errors

	UHF	IFF	TACAN	NAV-wpt.	STORES
a. Std. Control Heads	3.13*	3.31	3.75	3.13	3.44
b. H1	3.75	3.13	3.5	3.63	3.56
c. H2	3.56	3.13	3.5	3.5	3.56
d. H3	3.63	3.13	3.56	3.44	3.63
e. H4	3.06	2.63	3.0	2.88	3.0

*Each entry represents a mean of sixteen responses.

Comments:

- Secondary switches are nearly indistinguishable and extremely difficult to correlate in H4.

- Had more difficulty selecting appropriate multifunction switches than functional selection switches. Might have been solely due to parallax though.

- Need some definite indication that all switches are correctly set and weapons are armed. Typing in as opposed to throwing switches in a target area might prove disastrous. Once again, heads up is paramount.

- Most errors due to parallax on CRT.

- I made errors using H1 and H2 but it was because I kept hitting the wrong key on two keys at once.

- Further need to shift attention increases errors.

- H2 will produce more than the average errors because the buttons and CRT are on different sides of the cockpit, thereby slowing down and/or reducing the crosscheck. H4 is bad because the buttons are blank and hard to coordinate information from CRT on forward panel to buttons on lower side panel.

- This is vague.

- I consistently made an error utilizing the Tailored Mode NAV Bomb by not hitting the return button.

7. Rate the configurations listed below on the criterion of flying precision for the following tasks: UHF, IFF, TACAN, NAV-wpt., STORES. Use the rating scale: 1 = Excessive Interference, 2 = A Lot, 3 = Some, 4 = Negligible, 5 = No Interference

	UHF	IFF	TACAN	NAV-wpt.	STORES
a. Std. Control Heads	3.0*	3.0	3.38	2.63	3.56
b. H1	3.56	3.25	3.38	3.0	3.06
c. H2	3.5	3.0	3.25	2.88	2.88
d. H3	2.81	2.63	2.69	2.44	2.5
e. H4	2.69	2.5	2.63	2.25	2.28

*Each entry represents a mean of sixteen responses

Comments:

- Flying left handed is imprecise at best.

- All configurations requiring the use of the right hand downgraded flying precision.

- Assuming the use of autopilot, the keyboard on the right panel might be preferrable. Since the plane is not to be used in formation, you can pretty much use the autopilot all the time except in the target area, then the ease of changing weapon options becomes a factor.

- The amount of time required with head in cockpit would make it almost impossible to perform these tasks while flying formation in weather.

- H1 is the best because of location of controls and ability to fly with right hand. The others all seem to be bad because of crosscheck problems, or lack of it, and having to fly with left hand for excessive periods of time while operating MFK.

- The reason Standard Control Heads are rated high is because I am used to them, but I am sure H2 and H3 would be much better in the long run.

- Having to look at the lower right console (H3 and H4) would detract somewhat from my navigation proficiency.

8. Rate the relative importance of the three factors listed below with respect to successful mission completion. Check (✓) the appropriate box.

	Irrel-evant	Not Very Impor-tant	Impor-tant	Very Impor-tant	Essen-tial
a. <u>Flying Precision</u>		1	3	5	7
b. <u>Time</u> required to complete mission tasks (i.e. UHF change)		3	5	5	4
c. <u>Accuracy</u> in completion of mission tasks (i.e. UHF change)		1	5	1	9

Comments:

- Task management would make many functions more acceptable in low demand areas of flight.

- NAV updates and weapon selection/changes often have to be accomplished in a few seconds. I think I could do it as fast in the simulator as I can in the plane.

- "Aviate, Navigate, Communicate" still holds.

- Time is more critical in formation flying, not so much when alone.

- In a fighter, it is essential to spend as little time as possible looking inside the cockpit.

- Time is not relatively critical only because the actions are seldom required.

- Flying precision during enroute portion of mission is not the most important factor but it could be during the approach phase.

9. The control actions required on the digit entry keyboard (DEK) to correct erroneous digit selections were: Check (√) one

Very Difficult	Moderately Difficult	No Opinion	Moderately Easy	Very Easy
	2		4	10

Comments:

- The ability to erase the last entered digit is the best innovation since sliced bread.

- Thought it was super.

- One digit erase function is a nice feature.

- Dimple did not help in selection but did feel different when selected number five. Prefer all DEK keys uniform.

- Still think clear button should remove one digit at a time. Exit mode to clear or have another clear. "Data Entry" should be on left row of switches.

- Much better than A-7D.

- I liked it.

- Correction was easy during the demonstration, but I had trouble with corrections during the flight. Keyboard is good size. Did not feel the bump [on key 5].

- Push to clear all numbers on waypoint changes - not just last digit.

- Buttons should be smaller for tradeoff of providing more space between buttons.

- Better than present A-7 system for correcting errors.

- The digits 1 through 9 might be less error prone if [the switches were round instead of square].

- I like being able to erase only one digit or a part of the LAT/LONG entry.

III. SIMULATOR FEATURES

1. Compare the indicated features of the simulator with the A7. Check (✓) the appropriate box.

	Worse Than	Slightly Worse Than	Similar To	Slightly Better Than	Better Than
a. Throttle	2		14		
b. Control Stick	3	7	6		
c. VSD vs ADI	1	2	2	3	8
d. HSD vs HSI*	2	4	4	1	5
e. Status on MPD vs Status on Std. Control Heads	1	1	1	4	9

* Note: One subject made two selections, one subject did not respond.

Comments:

- Interference between throttle and DEK.

- Stick position very uncomfortable, too far forward.

- Status display was great.

- HSD is so much different from HSI that a direct comparison is difficult. I miss the compass rose. I often use the compass rose to quickly figure the angle between two headings instead of mentally subtracting the numbers.

- HSD and PMDS are similar, but the HSD does not have the map we have.

- I would like the control stick to control the flight director instead of the aircraft symbol. HSD and HSI are not comparable in my opinion. PMDS is much better than the HSD because you can see (navigate from) the surroundings on the PMDS. Programming known threats and landmarks on HSD would help.

- Control stick may be slightly too far forward. VSD would take some getting used to. Maybe a HSD superimposed over PMDS but never without PMDS. Too much information on MPD. "Think Dumb".

- MPD - Would not like quantity indications to change when weapon release occurs (except for option released) even though indications would be erroneous. Example:

Option 1	Q8
Option 2	Q12
Option 3	Q10
Option 4	Q18

If option 3 was selected and released, I would like to see:

Option 1	Q8
Option 2	Q12
Option 3	Q0
Option 4	Q18

In other words, I would like to see status remain as it currently is programmed rather than changed as has been considered.

- Stick forces or breakout forces appear slightly higher. VSD - No direct comparison, difficult to determine zero bank angle. Numerical information is not well defined.

- The VSD is a tremendous improvement over the ADI. All the good features of a HUD plus the digital scales make it truly an easy to read, single instrument display.

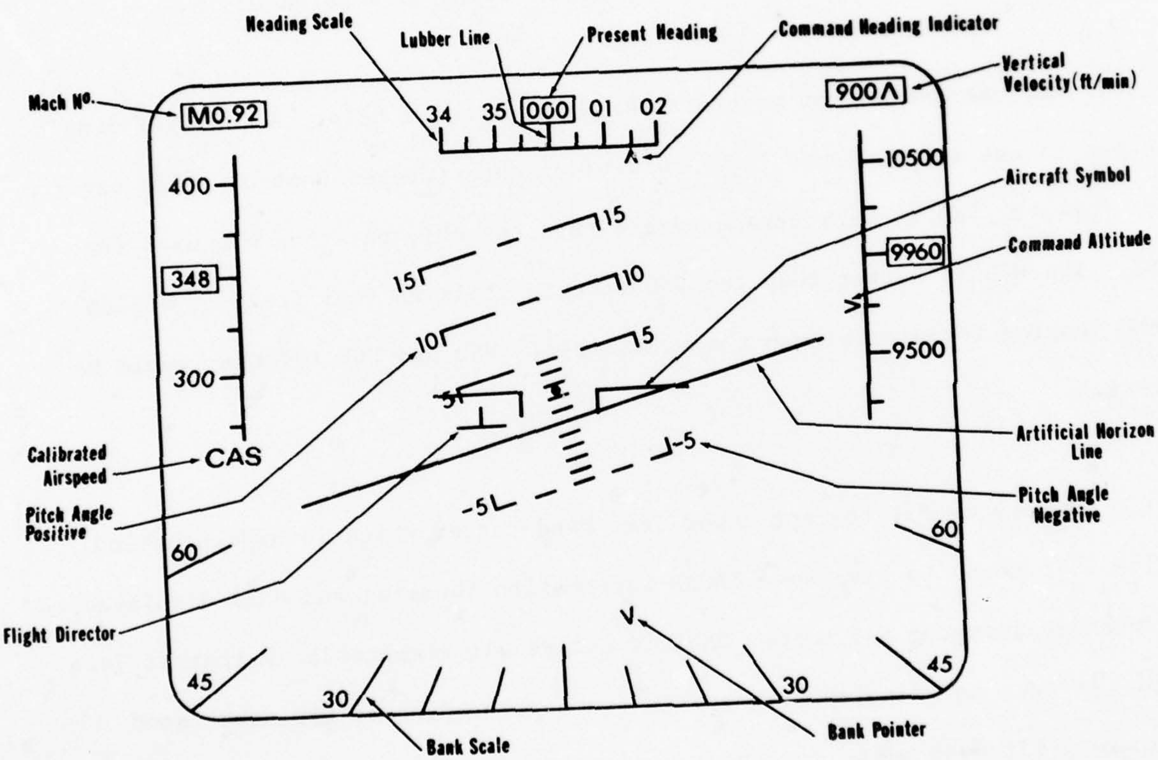
- VSD - Jitter and broken lines are distracting. HSD - HSI gives a better instantaneous reading of your status. PMDS much superior in practicality. MPD - Nice to have everything colocated, but some clutter. Control Stick - Dead band should be larger.

- In A-7D aircraft, power changes are made with reference to fuel flow meter. RPM is not a good power reference. TOT is also used in A-7. Instruments did not respond to throttle as they do in airplane. Stick does not feel realistic. VSD is hard to read. It needs a zero pitch line. Flight director symbol is unsatisfactory. Bank index is hard to read. Lines are broken. Airspeed and altitude scales are hard to read and are too small. CAS box should not cover scale. Altitude box should not cover scale. Heading box may not be necessary. Might be better to have lubber line similar to A-7 HUD. Vertical velocity should be displayed graphically rather than digitally. In

general VSD is not as good as A-7 ADI or HUD. HSD has some good points, but in general it appears to be inferior to A-7 HSI, especially HSI/PMDS combination. Good feature of HSD is that it shows track graphically with aircraft positon, however, PMDS gives some information as well as a map of the terrain and the PMDS is easier to interpret. PMDS is the most useful instrument in A-7D. I would like to see an improved version of it.

- Trim was useless if not more of a hindrance than a help. Actually I didn't bother to use it, and when I did, conditions deteriorated. Control stick was too far forward. VSD is much more accurate than the ADI, but then who uses the ADI. The HUD is better than the VSD because it is in your field of vision when looking forward through the windshield. VSD and HUD together would be great.

- HSD is very useful (except lower left hand corner which is hidden behind stick). It needs to have some TACAN information (bearing and DME) displayed on it without changing NAV mode. PMDS is not really comparable in that it is a map. It does not display turn points and next heading as HSD does (good feature). It does allow for updates however. VSD is great.



Heading Scale
Lubber Line
Present Heading
Command Heading Indicator
Vertical Velocity(ft/min)
900Λ
Mach No.
M0.92
34
35
000
01
02
10500
Aircraft Symbol
9960
Command Altitude
9500
400
348
300
CAS
15
10
5
-5
Artificial Horizon Line
Calibrated Airspeed
Pitch Angle Positive
Pitch Angle Negative
60
45
30
Flight Director
Bank Scale
Bank Pointer

2. VSD

Display Qualities (See Figure on Previous Page)

	Very Bad	Bad	No Opinion	Good	Very Good
a. Amount of Information		1		5	10
b. Information Retrieval	1			5	10
c. Legibility	1	2		3	10
d. Brightness		1		3	12
e. Shape of Symbols		1	2	3	10
f. Jitter		3	4	3	6

Comments:

- All CRT numbers need to be slightly larger.

- The use of black to highlight the altitude and airspeed is very good. It took a while to get used to VVI information and altitude information in terms of nearest foot.

- Super, readouts are great. Bank pointer should be larger and filled in.

- Sometimes too much information, requires excessive time to locate and assimilate desired information. VSD jitters slightly at horizon.

- A lot of information.

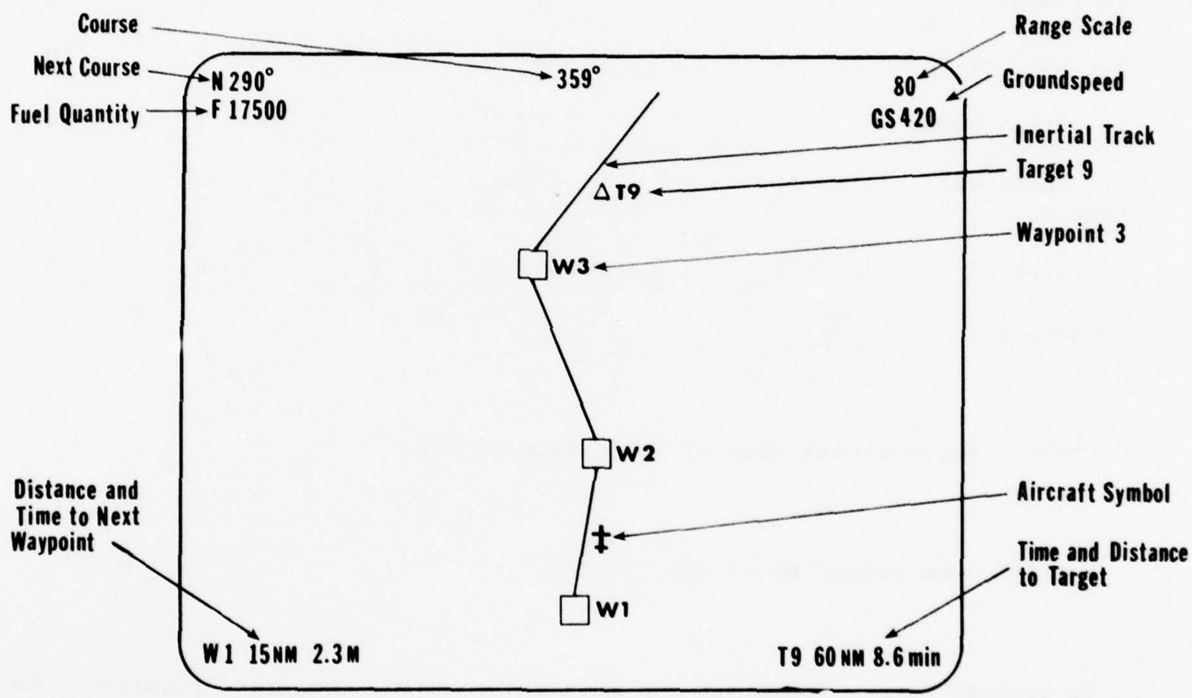
- Presents a lot of information but it is difficult to interpret. Legibility is poor. Characters are too small. No brightness rheostat. Colors could be better. Display undulates and lines are broken.

- Digits are too small. Horizon might be easier to use with a sharper contrast between blue and brown.

- Good instrument.

- Sometimes it is difficult to read the numbers and I have 20/20 vision. Looks a little out of focus.

- I really like the VSD!!


Course
Next Course
Fuel Quantity
N 290°
F 17500
359°
80
GS 420
Range Scale
Groundspeed
Inertial Track
Target 9
Waypoint 3
T9
W3
W2
W1
Aircraft Symbol
Distance and Time to Next Waypoint
Time and Distance to Target
W1 15NM 2.3M
T9 60NM 8.6min

3. <u>HSD</u>

Display Qualities (See Figure on Previous Page)

	Very Bad	Bad	No Opinion	Good	Very Good
a. Amount of Information		2	1	8	5
b. Information Retrieval		4	1	5	6
c. Legibility		2	2	2	10
d. Brightness		1		5	10
e. Shape of Symbols			2	5	9
f. Jitter		2	3	6	5

Comments:

- Control stick blocks view of lower part of HSD.

- Noticed some pulsating of the display.

- No compass rose. Sometimes too much information, requires excessive time to locate and assimilate desired information. Too cluttered at bottom and information is hidden behind stick. Should have distance remaining (waypoint information) in top right corner. Put range in bottom left where stick interferes. Knowing the range is not as critical. Suggest distance information be displayed over time to target information in lower right corner with a heading indication too. Distance, time-to-go and ground speed should be in proximity on the display.

- Lots of clutter - definitely need an HSI compass able to be displayed on CRT.

- All very pertinent information but needs TACAN bearing and DME.

- Gives a lot of information but it is hard to retrieve. Desired track is not shown on HSD. [This information is on HSD]. No brightness control. In general, it is more difficult to read than the PMDS and does not give pilot as useful information as the PMDS.

- Could not use. Did not provide enough information.

- Information presentation not very useful. Would be more useful with superimposed PMDS.

- Good instrument.

- I was bu3y doing the tasks so I didn't have a chance to look at the information on the HSD like I would have liked to.

- I would put the aircraft position in the center of the CRT and also put in a selectable scale option.

APPENDIX G

STATISTICAL PROCEDURES USED IN DATA ANALYSES

Amplitude distributions (Reference G1) of the time-history recordings of each parameter were constructed to evaluate the relative effects of the experimental conditions. Summary statistics descriptive of the error amplitude distribution of a sample of tracking performance were computed using the following formulae:

AE (average error) =

$$\frac{1}{T} \int_0^T e(t)\, dt$$

AAE (average absolute error) =

$$\frac{1}{T} \int_0^T |e(t)|\, dt$$

RMS (root-mean-square error) =

$$\sqrt{\frac{1}{T} \int_0^T e^2(t)\, dt}$$

SD (standard deviation) =

$$\sqrt{(RMS)^2 - (AE)^2}$$

where T = time over which the parameter was integrated

e = amplitude of the parameter at time t

dt = sampling interval

The AE is a numerical index of the central tendency of the amplitude distribution, while the SD reflects the variability of dispersion of the

measures around this central tendency. RMS error is also an index of performance variability, but relative to the null point rather than the AE. AAE is the mean of the amplitude distribution replotted with all error amplitudes positive and is indicative of the variability when interpreted in conjunction with the other performance indices.

These summary statistics (AE, AAE, RMS, SD) were computed on the flight parameters groundspeed, bank steering error, and pitch steering error for the time period specified by the event and for the immediate thirty seconds prior to the event. Summary statistics for the thirty second pre-event time for each parameter were subtracted from the corresponding values computed for the event in order to measure only the affect of the keyboard operations on the pilot's performance. An example calculation can be illustrated as follows:

Bank Error AAE		Bank Error AAE		Delta Bank AAE
(Time Period	-	(Pre-event	=	(Summary Statistic
for Correct		Period)		used in Statistical
Entry: Total try)				Analyses)

Keyboard task performance was evaluated by measuring the time required for the task event and the number of switch hits. Since the number of required switch hits was not the same for each type of task, a

Figure of Merit (FOM) was computed by dividing the actual number of switch hits by the number required to accomplish the keyboard operation without error. For example, 8 switch hits were required to change a TACAN channel correctly. Suppose a pilot made an error on the fifth switch hit, cleared the entry, and then entered the entire update correctly. The pilot then actually made 10 switch hits including the clear button in order to successfully complete the update. The FOM in this case would be:

$$\frac{10 \text{ (Actual number of switch hits made)}}{8 \text{ (Number of switch hits required to complete task without error)}} = 1.25$$

An error free task would produce a FOM of 1.0 and as errors increased, the FOM increased.

Statistical analyses were conducted on the following dependent variables:

- delta groundspeed AAE
- delta groundspeed RMS
- delta bank steering error AAE
- delta bank steering error RMS
- delta pitch steering error AAE
- delta pitch steering error RMS
- keyboard operation time
- figure of merit

These variables were initially analyzed by the use of the Biomedical (BMD) Statistical Computer Program 12V (Reference G2) which performs multivariate analysis of variance or covariance for any hierarchical design with equal cell sizes. In those cases where the MANOVA revealed significant effects, stepwise discriminant function analyses by the use of the BMD07M program were conducted. In performing a multiple group discriminant analysis, this program computes a set of linear classification functions by choosing the independent variables in stepwise manner. The variable entered at each step is selected by one of four available criteria, and a variable is deleted when its F-value becomes too low.

Data obtained from the debriefing questionnaire was compiled to be presented in tabular form (Appendix F). Nonparametric chi-square tests of significance were conducted. Since the expected frequencies were not sufficiently large to employ the test, the responses in adjacent categories were combined. For example, the responses to some of the questions were categorized as follows: worse than, slightly worse than, equal to, slightly better than, and better than. To increase the expected frequencies, adjacent categories were combined and the responses were categorized as follows: worse than, equal to, and better than (Reference G3).

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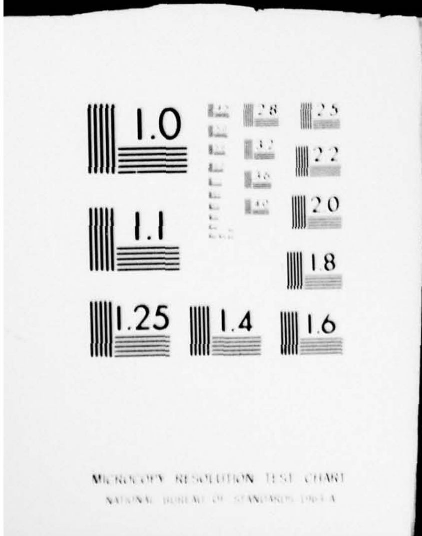

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